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REPORT NO. UMTA-MA-06-0044-79-1

DIESEL BUS PERFORMANCE SIMULATION PROGRAM

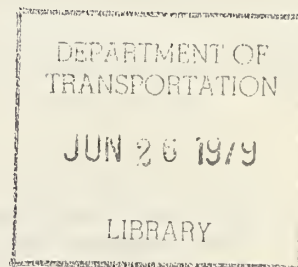
Glenn Larson
Harry Zuckerberg

U.S. DEPARTMENT OF TRANSPORTATION
RESEARCH AND SPECIAL PROGRAMS ADMINISTRATION
Transportation Systems Center
Cambridge MA 02142



APRIL 1979

FINAL REPORT



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Prepared for
U.S. DEPARTMENT OF TRANSPORTATION
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16. Abstract A diesel bus performance computer simulation program was developed. This program provides information on acceleration, velocity, horsepower, distance traveled, and fuel consumption as a function of time from the originating station. The program was written for diesel engine operation although heat engines other than diesel may be substituted. Fuel economy calculations, using the program, agree well with available measurements on urban buses and may be considered as representative of a baseline urban bus. Component submodels and vehicle coefficients used in the program have been carefully structured to represent current urban buses. This report includes a general description of the simulation program and the type of input data it required along with the results obtained by simulating a typical transit bus. DEPARTMENT OF TRANSPORTATION JUN 26 1979 LIBRARY			
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PREFACE

This report presents the technical basis of a diesel bus computer simulation program which was developed at the Transportation Systems Center for the Bus Technology Support Project, Urban Mass Transportation Administration, U.S. Department of Transportation. The computer program simulates the performance and predicts the fuel consumption of diesel-powered urban transit buses for any desired driving cycle. Driving cycles, presented for use in preliminary analyses, represent the upper and lower bounds of national urban bus driving cycles when considered from an energy point of view. The simulation program was developed for the study of the effect of various operating conditions and designs. The program listing is included.

Special mention should be made of the work of R. Hudson of Kentron International, Inc., who was responsible for programming the Diesel Bus Simulation Program.

METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures				Approximate Conversions from Metric Measures			
Symbol	When You Know	Multiply by	To Find	Symbol	When You Know	Multiply by	To Find
LENGTH				LENGTH			
in	inches	2.5	centimeters	mm	millimeters	0.04	inches
ft	feet	30	centimeters	cm	centimeters	0.4	inches
yd	yards	0.9	meters	m	meters	3.3	feet
m	miles	1.6	kilometers	km	kilometers	0.6	miles
AREA				AREA			
m ²	square inches	6.5	square centimeters	cm ²	square centimeters	0.16	square inches
ft ²	square feet	0.09	square meters	m ²	square meters	1.2	square yards
yd ²	square yards	0.8	square meters	km ²	square kilometers	0.4	square miles
mi ²	square miles	2.6	square kilometers	ha	hectares (10,000 m ²)	2.5	acres
	acres	0.4	hectares				
MASS (weight)				MASS (weight)			
oz	ounces	28	grams	g	grams	0.035	ounces
lb	pounds	0.45	kilograms	kg	kilograms	2.2	pounds
	short tons (2000 lb)	0.9	tonnes	t	tonnes (1000 kg)	1.1	short tons
VOLUME				VOLUME			
tsap	teaspoons	5	milliliters	ml	milliliters	0.03	fluid ounces
Tsp	tablespoons	15	milliliters	l	liters	2.1	pints
fl oz	fluid ounces	30	milliliters	l	liters	1.06	quarts
c	cups	0.24	liters	l	liters	0.26	gallons
pt	pints	0.47	liters	m ³	cubic meters	35	cubic feet
qt	quarts	0.95	liters	m ³	cubic meters	1.3	cubic yards
gal	gallons	3.8	liters				
ft ³	cubic feet	0.03	cubic meters				
yd ³	cubic yards	0.76	cubic meters				
TEMPERATURE (exact)				TEMPERATURE (exact)			
Fahrenheit temperature	5/9 (after subtracting 32)		Celsius temperature	Celsius temperature	9/5 (then add 32)		Fahrenheit temperature

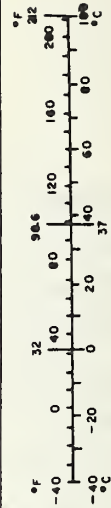


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1. INTRODUCTION

To develop propulsion systems for urban buses, it is important to have a bus simulation program which can be used for preliminary trade-off analyses. Since most urban buses are diesel powered, the Bus Simulation Program was written for diesel engine operation, although heat engines other than diesel may be substituted. This simulation may be considered representative of a baseline urban bus.

The modeling technique is similar to that described by N. Beachley and A. Frank¹. Component submodels and vehicle coefficients have been carefully structured to represent current urban buses. Fuel economy calculations, using the program, agree well with all available urban diesel bus fuel consumption data.

This report is divided into two main sections, Section 2, which presents a description of the computer simulation model, and Section 3, which gives the information necessary to operate the program. A complete listing of the program is included in Section 3.2.

¹Beachley, N.H. and Frank, A.A., "Digital Automotive Propulsion Simulator Programs and Description," Vol. II, Department of Electrical and Computer Engineering, University of Wisconsin - Madison, Contract No. DOT-OS-30112, Dec. 1974.

2. DESCRIPTION OF THE COMPUTER SIMULATION MODEL

The Diesel Urban Bus Simulation Program is designed to assess the performance and fuel consumption of buses under various operating conditions and with various power drives. The program will give energy distribution within the power drive of any synthesized vehicle design over specified transient and steady-speed driving patterns.

2.1 DRIVING CYCLE DEVELOPMENT

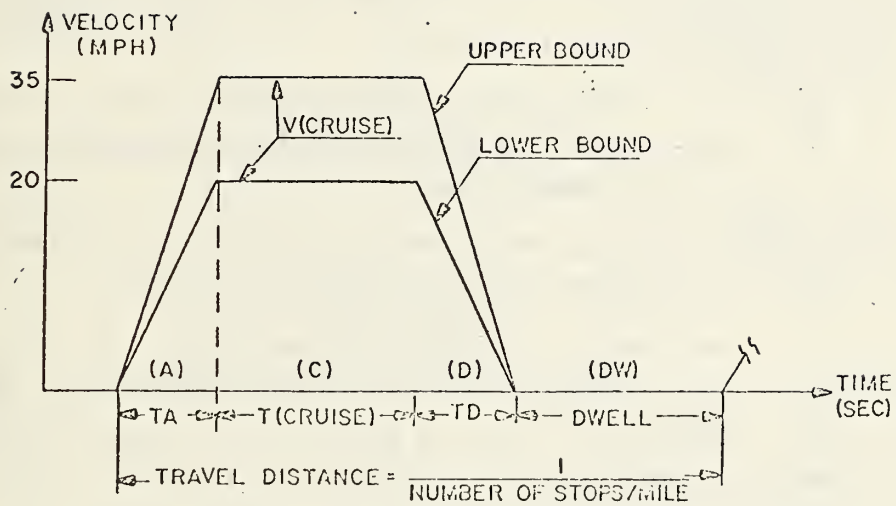
In order for the simulation model to provide useful comparisons of the various types of vehicle propulsion systems, it is necessary to use representative urban bus driving cycles. The cycles selected (see Figure 1) are based on the TRANSBUS and Small Bus specifications (References 2 and 3), work by Renner (Reference 4), and measurements made by TSC in the Boston area.

The simple drive cycles used in this analysis, assumed repetitive over any number of stops, are considered to represent the upper and lower bounds of urban bus driving cycles when considered from an energy point of view. During actual operation, buses are subjected to varying accelerations and cruising velocities within any one driving cycle and to varying numbers of stops per mile. However, in order to determine the performance behavior and the comparisons of different power drive subsystems, the use of simple repetitive drive cycles provides sufficient accuracy.

2.2 VEHICLE SIMULATION MODEL

To simulate the operation of a transit bus over a specified driving cycle for fuel consumption and emissions determinations, it is necessary to:

- a) Determine the sequence of engine operating conditions for each moment during the driving cycle.



ITEM	NOMENCLATURE	UPPER BOUND	LOWER BOUND
(A)	ACCELERATION MODE (CONSTANT ACCELERATION)	3.5 mphs	2.0 mphs
(C)	CRUISE MODE (CONSTANT VELOCITY)	35 mph	20 mph
(D)	DECELERATION MODE (CONSTANT DECELERATION)	3.4 mphs	2.5 mphs
(DW)	DWELL TIME AT BUS STOP	20 seconds	10 seconds

FIGURE 1. URBAN TRANSIT BUS DRIVING CYCLE LIMITS

- b) Determine from an engine map the instantaneous rate of fuel flow for each moment.
- c) Integrate the instantaneous fuel flow and vehicle velocity versus time to obtain the total fuel consumed and total distance traveled.
- d) Obtain fuel economy by dividing the total miles traveled by the total number of gallons of fuel consumed; similarly for vehicle emissions.

A generalized computational flow diagram which provides the basis for vehicle simulation is illustrated in Figure 2.

A typical urban bus was selected for modeling. It is a GMC model urban coach, equipped with an 8V-71' engine with N60 fuel injectors, coupled to a Detroit-Allison VH torque converter. The fully loaded vehicle weight, including passengers, driver, and miscellaneous weight is assumed to be 30,000 pounds. A weight breakdown is given in Table 1. Accessories mounted on the engine require up to 40 horsepower, which was subtracted from the total available output. The engine power and torque curves were provided by the Detroit Diesel Engine Division of GMC. Torque converter operating characteristics were provided by GMC's Detroit-Allison Division.

The computer program was developed to simulate all elements of the power drive subsystem for the transit bus operation over the selected driving cycle. The required power at the drive wheel was computed from drive cycle data, vehicle friction, aerodynamic drag, inertial acceleration, and rotational inertias. The corresponding power levels were computed throughout the power drive based on rotational speeds and torques, and component performance characteristics.

The basic computer simulation program is an adaptation of the University of Wisconsin computer program, described in Reference 1. Changes to the program included the subsystem component hardware characteristics and the specific governor-operation of the torque converter. The governor-operation schedule

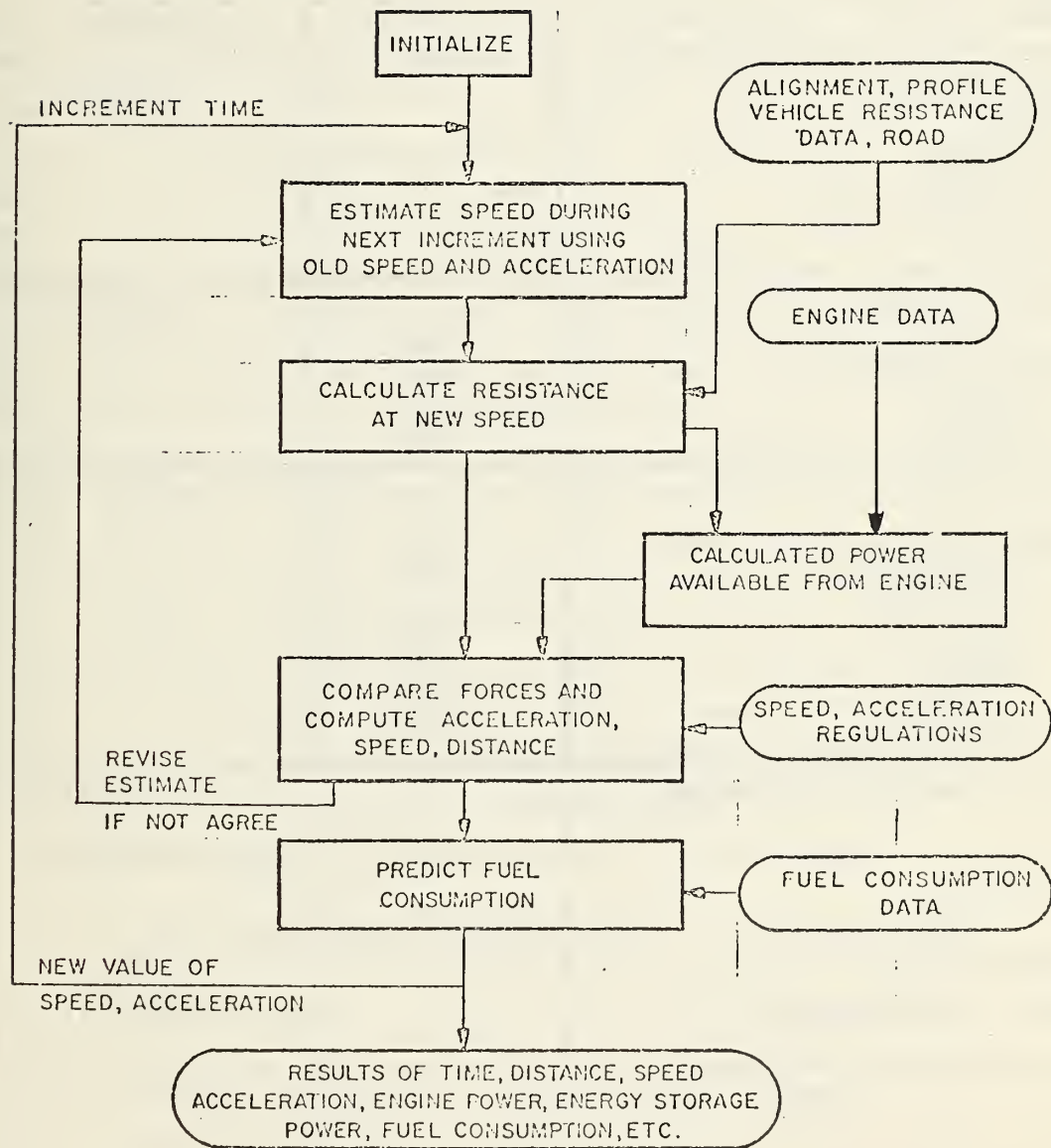


FIGURE 2. TRANSIT BUS VEHICLE COMPUTATIONAL FLOW MODEL

TABLE 1. TYPICAL TRANSIT BUS WEIGHT BREAKDOWN

ITEM	UNIT	SUB-TOTAL
Vehicle Body Shell Flooring Windows Interior Trim Seats		10,000 lb
Undercarriage Suspension Wheels, Tires Brakes Steering	1040 1360 1120 140	3,660 lb
Propulsion Rear Axle Transmission Power Plant Engine Radiator Exhaust Battery Fuel Tank	1280 500 2000 100 95 95 145	4,215 lb
Weight Empty, Curb Weight		18,275 lb
Payload Fuel, Oil Passengers, Crew		9,725 lb
Miscellaneous		2,000 lb
Gross Vehicle Weight		30,000 lb

relates the engine rpm with the vehicle velocity. The torque converter characteristics are illustrated in Table 2.

A simulation information flow diagram of the vehicle power model is illustrated in Figure 3. The nomenclature shown in the flow diagram is defined in the computer program discussion given in part II Section 3.2 of this report. Basic to the simulation model is the breakout of the vehicle mass. It can be shown that the kinetic energy of a moving body is made up of two components, one due to translation of the center of mass and one from rotation about the center of mass. A bus generally experiences only translation; however, an integral part of the vehicle, the power drive, consists of components which rotate as a function of the translational motion. Since the propulsion system must supply the power to produce the translational as well as the rotational energy, it is convenient to convert the kinetic energy of rotation to an equivalent kinetic energy of translation. This yields an equivalent mass (M_{EQ}) that must be added to the accelerated mass (M) of the vehicle. For preliminary calculations, an equivalent mass value of 10 percent can be used. However, in the computer the actual values of the equivalent mass are computed at every time interval.

The derivation of the equivalency is as follows:

$$(KE) \text{ (EQUIVALENT) TRANSLATION} = (KE) \text{ ROTATION}$$

$$\frac{1}{2} (MV^2)_{EQ} = \frac{1}{2} I_R \omega_{WH}^2$$

$$(M_{EQ}) (R_{WH} \omega_{WH})^2 = I_R \omega_{WH}^2$$

$$\text{or } M_{EQ} = I_R / R_{WH}^2.$$

Where I_R is the sum of the inertias of rotating members referred to the drive wheel side, R_{WH} is the drive wheel radius, and ω is the rotational speed.

TABLE 2. TORQUE CONVERTER CHARACTERISTICS

SR SPEED RATIO	TQR TORQUE RATIO	$\frac{1}{K^2} \times 10^{-4}$
0.000	3.820	2.5690
0.100	3.430	2.3760
0.200	2.950	2.1400
0.300	2.430	1.8210
0.400	2.010	1.5230
0.500	1.650	1.3200
0.600	1.300	1.1210
0.610	1.260	1.1000
0.620	1.230	1.0780
0.630	1.190	1.0500
0.640	1.150	1.0300
0.650	1.120	1.0150
0.660	1.080	0.9900
0.670	1.040	0.9750
0.680	1.010	0.9500
0.690	0.970	0.9200
0.700	0.930	0.8838
0.710	0.900	0.8300
0.720	0.860	0.7800
0.730	0.820	0.7600

$$SR = \text{SPEED RATIO} = \frac{\text{OUTPUT SPEED}}{\text{INPUT SPEED}}$$

$$TQR = \text{TORQUE AMPLIFICATION RATIO} = \frac{\text{OUTPUT TORQUE}}{\text{INPUT TORQUE}}$$

$\frac{1}{K^2}$ defined as the reciprocal of the input capacity factor, is given by:

$$\frac{1}{K^2} = \frac{\text{INPUT TORQUE}}{(\text{INPUT SPEED})^2}$$

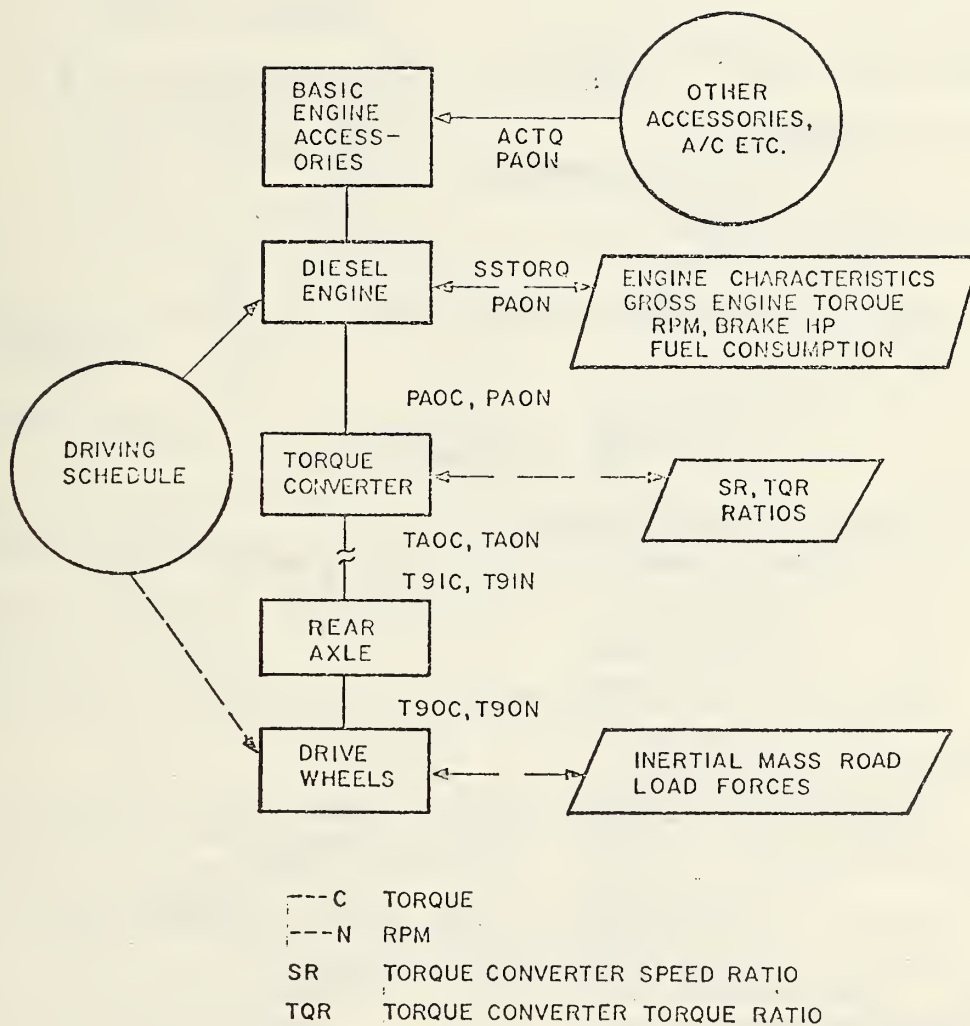


FIGURE 3. INFORMATION FLOW IN VEHICLE POWER DRIVE MODEL

2.3 POWER DRIVE COMPONENTS CHARACTERIZATION

The mechanical component arrangement shown in Figure 4 consists of:

Drive Wheel Speed of Rotation

Rotational speed (T90N) of drive wheels in terms of vehicle velocity (mph):

$$T90N = [(5280/60)/(2\pi R_{WH})]V$$

Drive Wheel Torque:

$$T90C = F_T \cdot R_{WH},$$

where R_{WH} = drive wheel rolling radius in feet

$$F_T = \text{road load}$$

$$= \text{inertial load} + \text{aerodynamic load} + \text{road resistance load.}$$

Drive Shaft Speed and Torque

$$\text{Drive shaft speed} = T91N = (RAR) (T90N)$$

$$\text{Drive shaft torque} = T91C = T90C/(RAR) (\eta_{RA}),$$

where RAR = rear axle ratio

$$\eta_{RA} = \text{rear axle efficiency.}$$

Input to Transmission

$$\text{Shaft speed} = TA0N = (TRGR) (T91N)$$

$$\text{Shaft torque} = TA0C = T91C/(TRGR) (\eta_{TR}),$$

where $TRGR$ is the transmission gear ratio (variable)
and η_{TR} the transmission efficiency,

Torque Converter

$$\text{Input speed} = PA0N = (SR) (TA0N)$$

$$\text{Input torque} = PA0C = (TQR) (TA0C)$$

where SR is the torque converter speed ratio
and TQR is the torque ratio,

The torque $PA0C$ is referred to the engine flywheel, which is the energy storage device. The flywheel absorbs transients in the engine rotational speeds as the velocity of the bus varies throughout the driving cycle.

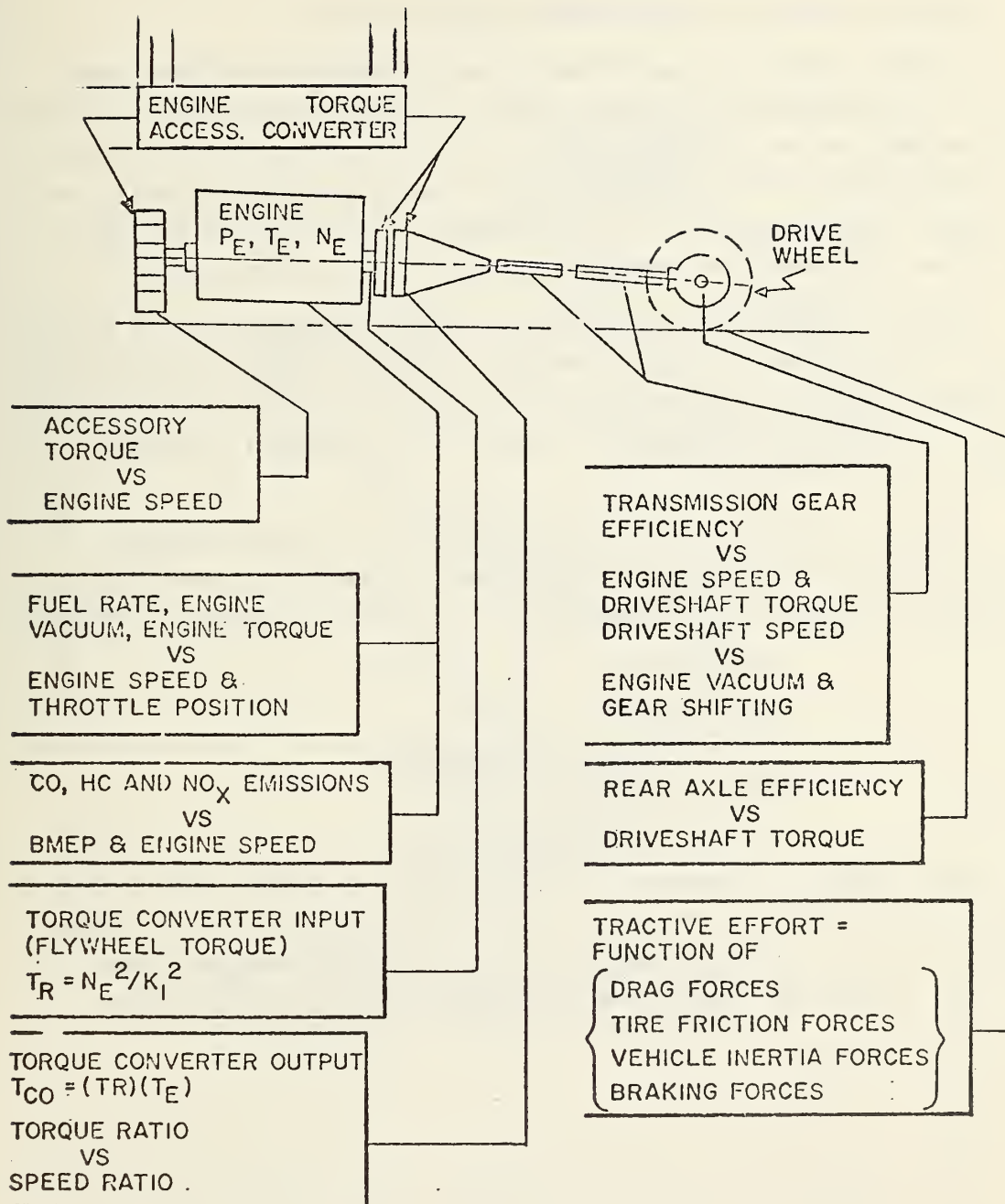


FIGURE 4. MOTOR VEHICLE POWER DRIVE SYSTEM

2.4 DIESEL URBAN BUS PERFORMANCE CALCULATIONS

A large number of performance calculations have been made using the simulation program. They correlate well when compared with actual urban bus data. Only in a few cases, however, are the data sufficiently characterized to make highly accurate comparisons. Well-measured bus performance and fuel consumption data over accurately determined driving cycles are needed.

Figure 5 shows the variation of fuel consumption with variation in the number of stops per mile for the lower bound driving cycle of Figure 1. Included in this figure are data points from high-confidence measurements, taken from equivalent driving cycles.

Figure 6 gives a plot of data obtained in fuel economy tests of a Flexible (ROHR) Transit Bus, driven on a test track, following Driving Cycle B (Reference 6) which is characterized by:

- acceleration - 3.0 mph/sec
- cruise speed - 30 mph
- deceleration - 3.4 mph/sec
- dwell time - 16 sec

Also shown in Figure 6 is a set of fuel economy points calculated by the Diesel Urban Bus Simulation Program for the same driving cycle. The correlation of the calculated values with the test values is considered to be quite good, within a few percent.

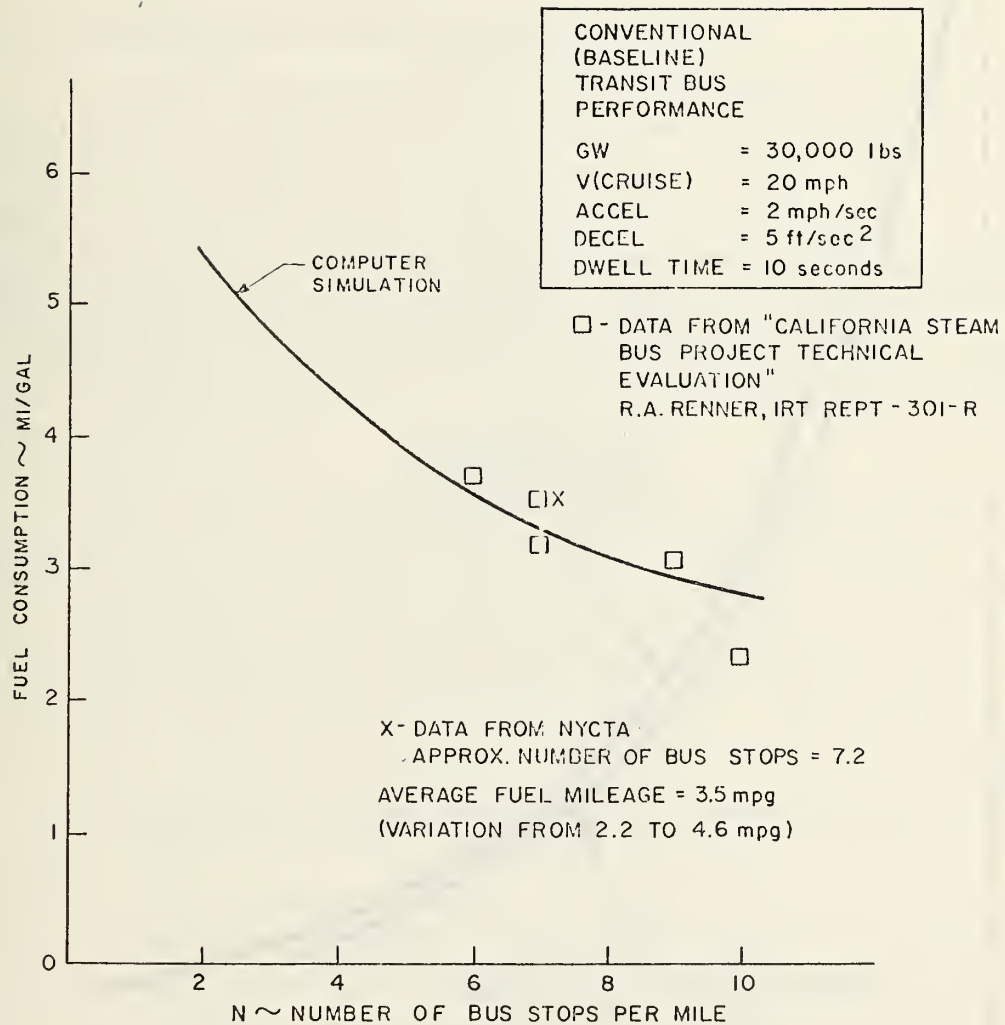


FIGURE 5. TRANSIT BUS PERFORMANCE

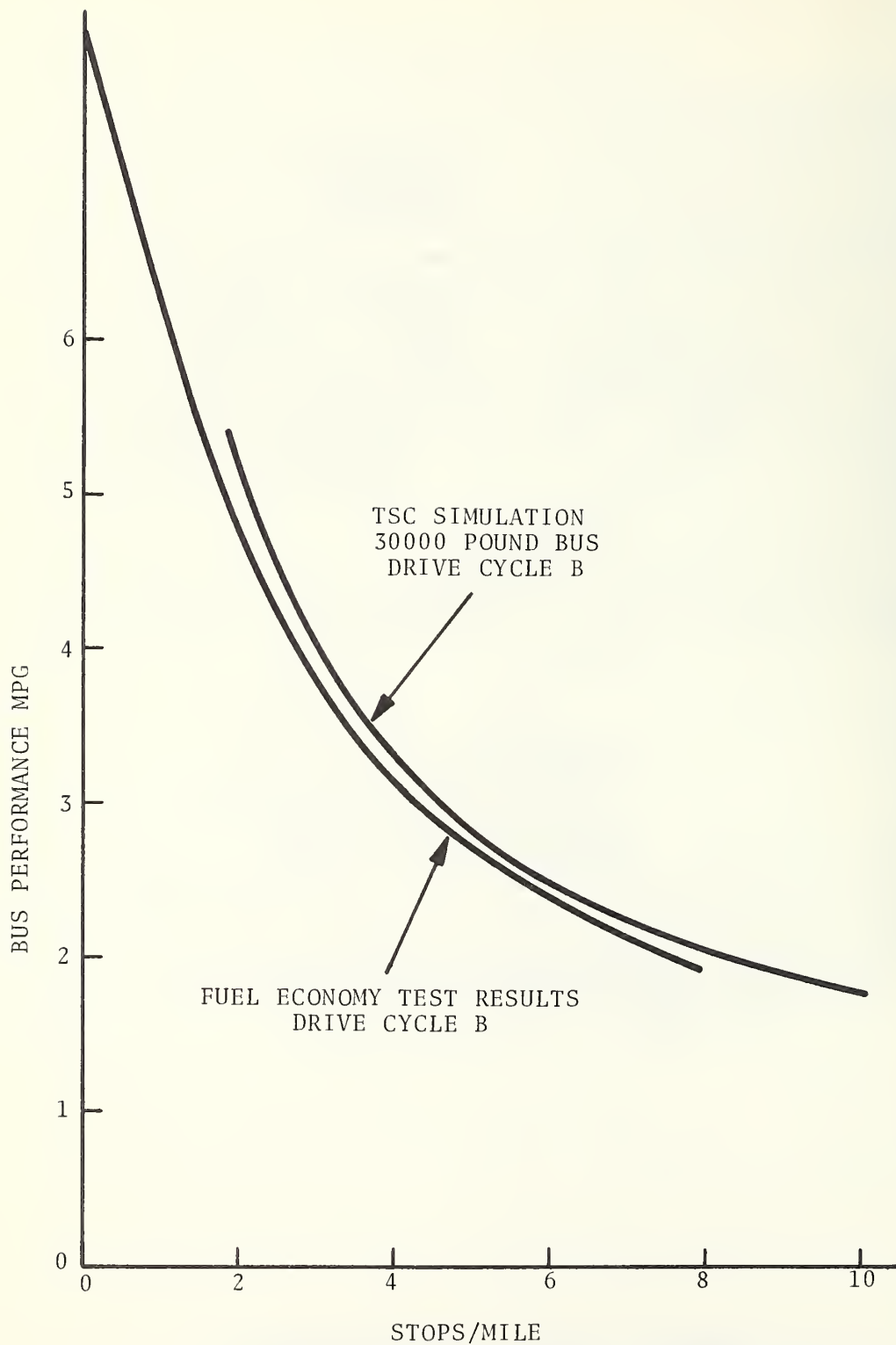


FIGURE 6. FLEXIBLE 870 BUS PERFORMANCE TEST RESULTS - DRIVING CYCLE B

3. MODEL OPERATION

3.1 DESCRIPTION OF COMPUTER SIMULATION MODEL

The diesel bus performance simulation model predicts the performance of vehicles with various power plants over any desired set of segments of a driving cycle. Each driving cycle segment has a specified length and grade, a dwell time or vehicle idling time (to simulate passenger loading and unloading), and a desired vehicle cruise speed. Actual vehicle performance is determined by solving Newton's equations of motion at regular time intervals subject to the constraints of engine and vehicle characteristics.

Output data include torque and horsepower, at the engine and at the tires' interfaces with the road; velocity and acceleration during each time period; engine speed; and fuel consumption. These data can be plotted as well as printed, permitting quick cross-comparisons among variables. Characteristics of the power plant and drive train are modeled in a series of subroutines; fuel consumption rate is calculated in another subroutine.

The simulation program receives input data, transmits output data, and initializes appropriate variables at the beginning of each driving cycle segment. It also includes all routing logic for determining whether the vehicle should be accelerating, decelerating, or cruising. A vehicle dynamics subroutine contains an integration algorithm to solve the equations of motion. A subroutine is provided to calculate fuel consumption when the vehicle is moving, and when it is stationary. A print subroutine handles output printing, and a plot subroutine handles output plotting using the standard software provided by CalComp.

An input subroutine specifies the subject vehicle, driving cycle configuration, and route terrain profile. The inputs are vehicle data, engine performance data, power drive characteristics, acceleration, cruising speed, deceleration, vehicle idle time at bus stops, number of bus stops per mile, grade profile

along route, head or tail winds, and adhesion characteristics between tires and road.

Calculations are performed to generate the following components of force acting on the vehicle:

- a) aerodynamic drag,
- b) gravity,
- c) wheel drag, and
- d) vehicle thrust.

The method used to calculate these factors depends upon the operational mode (acceleration, cruise, or deceleration) and the gear number in which the vehicle is presently operating. Thrust is constrained by the limits of tire-ground adhesion.

The model is written in the FORTRAN IV language and has been run. A model 663 CalComp plotter and associated software provide the graphic output. Since the model accumulates performance data from all driving cycle segments as they are computed, and prints and plots them at the end of a run; storage requirements are a function of the number of segments handled in a run.

In the program all dynamic variables are local or passed as parameters between the various subroutines. All the constants and tables are placed in labeled common files and accessed from there.

Following is a glossary of terms, constants, variables, tables, and arrays used in the program.

3.1.1 Glossary of Symbols

<u>SYMBOL</u>	<u>NAME</u>	<u>DESCRIPTION</u>
FIG. 3	ACLOAD(10)	ACCESSORY LOAD AS A FUNCTION OF ENGINE SPEED
T _A	ACTORQ	ACCESSORY LOAD
	ATORGS(60)	ENG TORS RECORDED SINCE LAST GENERAL OUTPUT
P	AVIB	AIR PRESSURE (PSI)
	AVIM	AIR DENSITY (LB/FT**3)

<u>SYMBOL</u>	<u>NAME</u>	<u>DESCRIPTION</u>
	AVIR	AIR TEMPERATURE (°F)
ϕ	AVIO	GRADE ANGLE (RAD)
V_W	AVIS	WIND SPEED (MPH)
T_{CI}	BAOC	CONVERTER INPUT TORQUE
N_{CI}	BAON	CONVERTER INPUT SPEED (RPM)
B_S	BS	BRAKE SETTING
FC	BSFC	BRAKE SPECIFIC FUEL CONSUMPTION
	COMM(26)	COMMENT CARDS FOR HEADING TITLES
ΔT	DELTA	INTEGRATION TIME STEP (SEC)
Δt	DELT	LEAD TIME FOR NEXT CYCLE VELOCITY IN AUTO DRIVER
	DT	TIME OF ONE CLOCK PULSE
	EPS	USED TO TEST FOR CONSTANT ENGINE SPEED
N_E	ESDOT	ENGINE ACCELERATION (RPM/SEC)
	ESDOTO	PREVIOUS VALUE OF ENGINE ACCELERATION
	ESPEED(60)	ENG SPDS RECORDED SINCE PREVIOUS GENERAL OUTPUT
	FTIME(60)	TIMES AT WHICH ESPEED AND ATORGs ARE SAVED
FW	FUELWT	WEIGHT OF ONE GALLON OF FUEL
TFC	FUELE	CUMULATIVE FUEL CONSUMED (LBS)
	GR1	RATIO OF FIRST GEAR
	HRPSEC	HOURS PER SECOND
	LBC1GI(10)	INDEX FOR ASSIGNING GEAR EFFICIENCY CALCULATIONS
T_P	1 CLOCK	CUMULATIVE NUMBER OF CLOCK PULSES
	1CLOKO	TIME AT PREVIOUS OUTPUT OF VARIABLES
T_{PO}	1CLOK1	1CLOCK AT COMPLETION OF LAST INTEGRATION
	ICYCLE	NUMBER OF TIMES THE PROGRAM HAS ITERATED
	ICYEND	END OF DRIVING CYCLE INDICATOR
	IGEAR	GEAR SHIFT INDICATOR
	INDIC	OUTPUT INDICATOR

<u>SYMBOL</u>	<u>NAME</u>	<u>DESCRIPTION</u>
	IOUT	NUMBER OF CLOCK PULSES ALLOWED BETWEEN OUTPUTS
	IPAOF(18,20)	FUEL CONSUMP AS FUNCTION OF ENG SPD AND LINE NO
	IPDX(20,20)	JOINT PROBABILITY DENSITY DIS- TRIBUTION
	ISHIFT	ICLOCK AT START OF LAST SHIFT
	ISPEED(20)	INT STORAGE FOR PRINTOUT OF SPD FOR JNT PROS DEN
	ITICYC	ICLOCK AT START OF DRIVING CYCLE
	IVEPA(685)	AUTO DRIVING CYCLE VELOCITIES AT 1 SEC INTERVALS
	LOADEQ	ROAD LOAD CALCULATION CONTROL
	LOCK	INDICATES IF CONVERTER IS LOCKED UP
	MAP1(55,17)	STEADY STATE ENG TRQ AS FUNCT OF THROTTLE AND ENG SPD
	MAP3(17,17)	FUEL RATE AS A FUNCTION OF ENGINE SPEED AND ENGINE TORQUE
	MAXLIN	MAXIMUM NUMBER OF LINES SPECIFIED PER PAGE
	NDIM(2)	NUMBER OF VARIABLES USED IN JOINT PROB DENSITY
	NFUEL	NUMBER OF ELEMENTS IN FUEL ARRAY
	NGEAR	NUMBER OF TRANSMISSION GEAR RATIOS
	NG1	CURRENT GEAR NUMBER
	NG10LD	GEAR AT PREVIOUS ITERATION
	NGT(2)	NUMBER OF SAMPLES WHICH EXCEED VMAX(1 AND 2)
	NLINE	NUMBER OF LINES ON CURRENT PAGE
	NLT(2)	NUMBER OF SAMPLES LESS THAN VMIN (1 AND 2)
	NREC	OUTPUT RECORD NUMBER
	NRUN	RUN NUMBER
	NVEPA	NUMBER OF VELOCITIES SPECIFIED IN DRIVING CYCLE
	NVOLT(15)	VOLTAGES FOR DACS AND ADCS
HP	OBHP	OBSERVED BRAKE HORSEPOWER
T _E	PAOC	ENGINE SHAFT TORQUE (ALSO REFERRED TO AS FLYWHEEL TRQ)

<u>SYMBOL</u>	<u>NAME</u>	<u>DESCRIPTION</u>
	PAOFR	FUEL CONSUMPTION RATE (LB/HR)
	PAOFRO	PREVIOUS VALUE OF PAOFR
N_E	PAON	ENGINE SPEED (RMP)
J_E	RIE	ENGINE INERTIA (LBM FT SQD)
	RIEINV	INVERSE OF ENGINE INERTIA
	SCALEF	ENGINE SIZE SCALE FACTOR
T_{SS}	SSTORQ	STEADY STATE ENGINE TORQUE
SR	TA11SR	SPEED RATIO
$1/K_I^2$	TAI3IK	INVERSE SQUARE OF SIZE FACTOR
K_I	TAI3KI	SIZE FACTOR
TR	TAO1TR	CONVERTER TORQUE RATIO
T_{CO}	TAOC	CONVERTER OUTPUT TORQUE
N_{CO}	TAON	CONVERTER OUTPUT SPEED
	TBC1G1(10,4)	POLYNOMIAL COEFFICIENTS FOR CALCULATING GEAR EFFICIENCY
	TBC1GR(10)	GEAR RATIOS
	TBDTH	MINIMUM TIME ALLOWED BETWEEN SHIFTS
	TBDTMS	LENGTH OF TIME FOR SHIFTING
η_{TR}	TBO1EF	TRANSMISSION EFFICIENCY
GI	TBO1GI	TRANSMISSION GEAR INDEX
GR_{TR}	TBO1GR	TRANSMISSION GEAR RATIO
	TCEFF	TORQUE CONVERTER EFFICIENCY
	TIDLE	THROTTLE IDLE SETTING
T	TIME	TIME FROM START OF DRIVING CYCLE (SEC)
	TIMAVG(5)	TIMER AVERAGES
	TIMLEN(5)	TIMER LENGTHS
	TIMMAX(5)	TIMER MAXIMUMS
	TMAS	MAXIMUM ENGINE TORQUE
	TORO	RATIO OF STEADY STATE TORQUE TO MAXIMUM TORQUE
T_S	TS	THROTTLE SETTING

<u>SYMBOL</u>	<u>NAME</u>	<u>DESCRIPTION</u>
J_{CT}	TVIJCT	MOMENT OF INERTIA OF TORQUE CONVERTER TURBINE
J_{RA}	TVIJRA	MOMENT OF INERTIA OF REAR AXLE GEARS
J_{TR}	TVIJTR	MOMENT OF INERTIA OF TRANSMISSION GEARS
J_{TW}	TVIJTW	MOMENT OF INERTIA OF TIRES AND WHEELS
	TVICRL(16)	ROAD LOAD TORQUE AT DRIVESHAFT
J	TVIMJ	TOTAL MOMENT OF INERTIA OF DRIVETRAIN
N_{DSU}	T8DN	UNCORRECTED DRIVE SHAFT SPEED
GR_{RA}	T811GR	NOMINAL REAR AXLE RATIO
	T8INV(11)	DRIVESHAFT SPEED AS A FUNCTION OF VEHICLE SPEED
GR_{RA}	T911GR	EFFECTIVE REAR AXLE RATIO
T_{DS}	T9IC	DRIVESHAFT TORQUE
N_{DS}	T9IN	DRIVESHAFT SPEED
T_{RA}	T90C	REAR AXLE TORQUE
	T9I1	REAR AXLE EFFICIENCY
n_{RA}	VAL(2)	VALUES OF VARIABLES FOR CALL TO PRBDEN
	VAR(10)	EXTRA SPACE FOR VARIABLES
V_i	VEPA	NEXT DRIVING CYCLE VELOCITY
	VINT(2)	INTERVAL SIZE FOR JOINT PROBABILITY DENSITY
	VMAX(2) PROBABILITY DEN	MAXIMUM VALUES FOR JOINT PROBABILITY DENSITY
	VMIN(2)	MINIMUM VALUES FOR JOINT PROBABILITY DENSITY
F_D	VVDF	SUM OF DRAG FORCES AND FRICTION (LBF)
	VVDMI	EQUIVALENT MASS OF VEHICLE (SLUGS)
C_D	VVI1CD	DRAG COEFFICIENT
C_F	VVI1CF	TIRE COULOMB FRICTION COEFFICIENT
μ	VVI1RF	ROLLING FRICTION COEFFICIENT

<u>SYMBOL</u>	<u>NAME</u>	<u>DESCRIPTION</u>
K_B	VVI2BR	BRAKE CONSTANT (USUALLY STATIC WEIGHT OF VEHICLE)
A_{MAX}	VVIAMX	MAX. ACCEL. (G'S) BASED ON MAX COEFF OF TIRE FRICTION
A_{MAXS}	VVIAS	MAX ACCEL. (G'S) BASED ON SLIDING COEFF OF TIRE FRICTION
R_T	VVIDRR	TIRE RADIUS
f_M	VVIFUM	MAXIMUM COEFFICIENT OF TIRE FRICTION
f_s	VVIFUS	SLIDING COEFFICIENT OF TIRE FRICTION
A_F	VVILFR	FRONTAL AREA (SQ FR)
M	VVIM	VEHICLE MASS (LBM)
M_{DR}	VVIMDR	MASS ON DRIVE SHEELS
M_I	VVIMI	INERTIAL MASS OF VEHICLE
H	VVISH	HEIGHT OF VEHICLE CENTER OF GRAVITY (IN)
WB	VVISWS	WHEEL BASE (IN)
A	VVOA	VEHICLE ACCELERATION (FT/SEC/SEC)
	VVOAO	PREVIOUS VALUE OF VVOA
D	VVOD	VEHICLE DISTANCE TRAVELED (MILES)
V	VVOS	VEHICLE SPEED (MPH)
	VVOSO	PREVIOUS VALUE OF VVOS
	WHLOLD	PREVIOUS VALUE OF WHEEL SLIP INDICATOR
	WHLSLP	WHEEL SLIP INDICATOR
	X(225)	DUMMY ARRAY FOR TAPE OR DISK OUTPUT

3.1.2 Glossary of Constants

<u>CONSTANT</u>	<u>MEANING</u>
AVIB	AIR PRESSURE (psi)
AVIM	AIR DENSITY (LB/FT ³)
AVIR	AIR TEMPERATURE (F)
DT	TIME OF ONE CLOCK PULSE
EPS	USED TO TEST FOR CONSTANT ENGINE SPEED
FUELWT	WEIGHT OF ONE GALLON OF FUEL
FR1	RATIO OF FIRST GEAR
HRPSEC	HOURS PER SECOND
IOUT	NUMBER OF CLOCK PULSES ALLOWED BETWEEN OUTPUTS
IPRNT	PRINT CONTROL
LOADEQ	ROAD LOAD CALCULATION CONTROL
MAXLIN	MAXIMUM NUMBER OF LINES SPECIFIED PER PAGE
NGEAR	NUMBER OF TRANSMISSION GEAR RATIOS
NVEPA	NUMBER OF VELOCITIES SPECIFIED IN DRIVING CYCLE
RIE	ENGINE INERTIA (LBM-FT ²)
RIEINV	INVERSE OF ENGINE INERTIA
SCALEF	ENGINE SIZE SCALE FACTOR
T8I1GR	NOMINAL REAR AXLE RATIO
TBDTH	MINIMUM TIME ALLOWED BETWEEN SHIFTS
TBDTMS	LENGTH OF TIME FOR SHIFTING
TIDLE	THROTTLE IDLE SETTING
TMAX	MAXIMUM ENGINE TORQUE
TVIJCT	MOMENT OF INERTIA OF TORQUE CONVERTER TURBINE
TVIJRA	MOMENT OF INERTIA OF REAR AXLE GEARS
TVIJTR	MOMENT OF INERTIA OF TRANSMISSION GEARS
TVIJTW	MOMENT OF INERTIA OF TIRES AND WHEELS
VACMAX	MAXIMUM MANIFOLD VACUUM (IN OF HG)
VVI1CD	DRAW COEFFICIENT
VVI1CF	TIRE COULOMB FRICTION COEFFICIENT
VVI1RF	ROLLING FRICTION COEFFICIENT
VVI2BR	BRAKE CONSTANT (USUALLY STATIC WEIGHT OF VEHICLE)
VVIAMX	MAX ACCEL (G'S) BASED ON MAX COEFF OF TIRE FRICTION
VVIAS	MAX ACCEL (G'S) BASED ON SLIDING COEFF OF TIRE FRICTION

<u>CONSTANT</u>	<u>MEANING</u>
VVIDRR	TIRE RADIUS
VVIFUM	MAXIMUM COEFFICIENT OF TIRE FRICTION
VVIFUS	SLIDING COEFFICIENT OF TIRE FRICTION
VVILFR	FRONTAL AREA (SQ FT)
VVIM	VEHICLE MASS (LBM)
VVIMDR	MASS ON DRIVE WHEELS
VVISH	HEIGHT OF VEHICLE CENTER OF GRAVITY (IN)
VVISWB	WHEEL BASE (IN)

3.1.3 Glossary of Dynamic Variables

<u>VARIABLE</u>	<u>MEANING</u>
ACTORQ	ACCESSORY LOAD
AVIO	GRADE ANGLE (RAD)
AVIS	WIND SPEED (MPH)
BS	BRAKE SETTING
DELT	LEAD TIME FOR NEXT CYCLE VELOCITY IN AUTO DRIVER
DELTA	INTEGRATION TIME STEP (SEC)
EMISE	EMISSIONS (NOT USED)
EMISF	EMISSION RATE (NOT USED)
ESDOT	ENGINE ACCELERATION (RPM/SEC)
ESDOTO	PREVIOUS VALUE OF ENGINE ACCELERATION
FUELE	CUMULATIVE FUEL CONSUMED (LBS)
ICLOCK	CUMULATIVE NUMBER OF CLOCK PULSES
ICLOKO	TIME AT PREVIOUS OUTPUT OF VARIABLES
ICLOK1	ICLOCK AT COMPLETION OF LAST INTEGRATION
ICYCLE	NUMBER OF TIMES THE PROGRAM HAS ITERATED
ICYEND	END OF DRIVING CYCLE INDICATOR
IGEAR	GEAR SHIFT INDICATOR
IGO	GO SWITCH INDICATOR
INDIC	OUTPUT INDICATOR
ISHIFT	ICLOCK AT START OF LAST SHIFT
ITICYC	ICLOCK AT START OF DRIVING CYCLE
NGI	CURRENT GEAR NUMBER
NLINE	NUMBER OF LINES ON CURRENT PAGE

<u>VARIABLE</u>	<u>MEANING</u>
NFUEL	NUMBER OF ELEMENTS IN FUEL ARRAY
NGIOLD	GEAR AT PREVIOUS ITERATION
NREC	OUTPUT RECORD NUMBER
NRUN	RUN NUMBER
OBHP	OBSERVED BRAKE HORSEPOWER
PAOC	ENGINE SHAFT TORQUE (ALSO REFERRED TO AS FLYWHEEL TRQ)
PAOFT	FUEL CONSUMPTION RATE (LB/HR)
PAOFRO	PREVIOUS VALUE OF PAOFT
PAON	ENGINE SPEED (RMP)
PPOB	ENGINE VACUUM (IN. OF HG.)
SSTORQ	STEADY STATE TORQUE
T8DN	UNCORRECTED DRIVE SHAFT SPEED
T9I1GR	EFFECTIVE REAR AXLE RATIO
T9IC	DRIVESHAFT TORQUE
T9IN	DRIVESHAFT SPEED
T90C	REAR AXLE TORQUE
T90N	DRIVESHAFT SPEED
TAI1SR	SPEED RATIO
TAI3IK	INVERSE SQUARE OF SIZE FACTOR
TAI3KI	SIZE FACTOR
TAO1TR	CONVERTER TORQUE RATIO
TAOC	CONVERTER OUTPUT TORQUE
TAON	CONVERTER OUTPUT SPEED
TBO1EF	TRANSMISSION EFFICIENCY
TBO1GI	TRANSMISSION GEAR INDEX
TBO1GR	TRANSMISSION GEAR RATIO
TIME	TIME FROM START OF DRIVING CYCLE (SEC)
TORQ	RATIO OF STEADY STATE TORQUE TO MAXIMUM TORQUE
TS	THROTTLE SETTLE
TVIMJ	TOTAL MOMENT OF INERTIA OF DRIVETRAIN
VEPA	NEXT DRIVING CYCLE VELOCITY
VVDF	SUM OF DRAG FORCES AND FRICTION (LBF)
VVDMI	EQUIVALENT MASS OF VEHICLE (SLUGS)
VVOA	VEHICLE ACCELERATION (FT/SEC/SEC)

<u>VARIABLE</u>	<u>MEANING</u>
VVOAO	PREVIOUS VALUE OF VVOA
VVOD	VEHICLE DISTANCE TRAVELED (MILES)
VVOS	VEHICLE SPEED (MPH)
VVOSO	PREVIOUS VALUE OF VVOS
WHLOLD	PREVIOUS VALUE OF WHEEL SLIP INDICATOR
WHLSLP	WHEEL SLIP INDICATOR

3.1.4 Glossary of Logic Variables

INISAT	0 - INITIALIZATION OF ENGINE SPEED COMPLETE. CAR IN NEUTRAL.
	1 - ENGINE BEING INITIALIZED. CAR IN NEUTRAL.
IREADY	0 - ENGINE NOT IN STEADY STATE.
	1 - GO LIGHT TURNED ON.

3.1.5 Glossary of Tables

<u>TABLE</u>	<u>MEANING</u>
ACLOAD(10)	ACCESSORY LOAD AS A FUNCTION OF ENGINE SPEED
COMM(26)	COMMENT CARDS FOR HEADING TITLES
IBC1GI(10)	INDEX FOR ASSIGNING GEAR EFFICIENCY CALCULATIONS
IVEPA(685)	AUTO DRIVING CYCLE VELOCITIES AT 1 SEC INTERVALS
MAP1(10,17)	STEADY STATE TORQUE AS A FUNCTION OF THROTTLE AND ENGINE SPD
MAP3	FUEL CONSUMPTION AS A FUNCTION OF TORQUE AND ENGINE SPEED
NDIM(2)	NUMBER OF VARIABLES USED IN JOINT PROB DENSITY
T8INV(11)	DRIVE SHAFT SPEED AS A FUNCTION OF VEHICLE SPEED
TAI3KP(20)	SIZE FACTOR AS A FUNCTION OF SPEED RATIO (NOT USED)
TBC1GI910,4)	POLYNOMIAL COEFFICIENTS FOR CALCULATING GEAR EFFICIENCY
TBC1GR(10)	GEAR RATIOS
TV1CRL(16)	ROAD LOAD TORQUE AT DRIVESHAFT
VINT(2)	INTERVAL SIZE FOR JOINT PROBABILITY DENSITY
VMAX(2)	MAXIMUM VALUES FOR JOINT PROBABILITY DENSITY
VMIN(2)	MINIMUM VALUES FOR JOINT PROBABILITY DENSITY

3.1.6 Glossary of Arrays

<u>ARRAY</u>	<u>MEANING</u>
ATORQS(60)	ENG TRQS RECORDED SINCE LAST GENERAL OUTPUT
ESPEED(60)	ENG SPDS RECORDED SINCE PREVIOUS GENERAL OUTPUT
FTIME(60)	TIMES AT WHICH ESPEED AND ATORQS ARE SAVED
IPDX(20,20)	JOINT PROBABILITY DENSITY DISTRIBUTION
ISPEED(20)	INT STORAGE FOR PRINTOUT OF SPD FOR JNT PROB DEN
NGT(2)	NUMBER OF SAMPLES WHICH EXCEEDED VMAX(1 AND 2)
NLT(2)	NUMBER OF SAMPLES LESS THAN VMIN (1 AND 2)
NVOLT(15)	VOLTAGES FOR DACS AND ADCS
TIMAVG(5)	TIMER AVERAGES
TIMLEN(5)	TIMER LENGTHS
TIMMAX(5)	TIMER MAXIMUMS
VAL(2)	VALUES OF VARIABLES FOR CALL TO JPB DEN
VAR(10)	EXTRA SPACE FOR VARIABLES
X(225)	DUMMY ARRAY FOR TAPE OR DISK OUTPUT
AWAY(20,3)	SPEED RATIO, TORQUE RATIO AND INVERSE SIZE FACTOR FOR TORQUE CONVERTER

3.2 BUS SIMULATION PROGRAM LISTING

The bus simulation program, Simula, is listed below.

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BUS SIMULATION PROGRAM
1: *
2: SUBROUTINE SIMULA
3: C**** BUS MODIFICATIONS DONE BY RICHARD HUDSON
4: COMMON /ENGINE/SCALEF,TIDLE,EVS,TS
5: DIMENSION NLT(2),NGT(2)
6: COMMON /LOCK1/ ACCLOCK,DECLOCK
7: COMMON /LOCK2/ ACCRDIS
8: DIMENSION MAP1(55,17),MAP3(17,17)
9: COMMON /MAPS/ MAP1,MAP3
10: COMMON /PRNT/ IBUT,IPRNT,LOADEQ,MAXLIN
11: COMMON /STEADY/ EPS
12: COMMON /TIME/ DT
13: DIMENSION IPDY(20,20)
14: COMMON IPDX
15: COMMON TEST(3),FTIME(60),ESPEED(60),ATORDS(60)
16: COMMON DRGHP(140),RAYHP(140)
17: COMMON XGBHP(140),ACCRP(140),FLYHP(140),CONHP(140)
18: COMMON TIMMAX(5),TIMLEN(5),TIMAVG(5),VAR(2)
19: COMMON XTACC(140),XTDEC(140),XT90C(140),GEAR(140)
20: COMMON XTIME(140),XSTOR(140),XPA0C(140),XACTOR(140)
21: C PLACED IN COMMON FOR STORAGE REASONS
22: INTEGER UDNSFT
23: LOGICAL
24: C---- INITIALIZE ALL CONSTANTS AND TABLES
25: *
26: *
27: CALL INICON
28: C---- OUTPUT CONSTANTS ON TAPE
29: C---- ENGINE MAPS
30: CALL MAPR
31: 5 CONTINUE
32: NRUN=NRUN+1
33: N=1
34: C---- CHANGE INITIALIZED CONSTANTS FOR NEW RUN
35: CALL AGNCON
36: C---- READ IN DRIVING CYCLE
37: CALL RDEPA
38: CALL OUTCON
39: C----- OUTPUT CONSTANT TO THE LINE PRINTER
40: CALL PRICON
41: C---- INITIALIZE VARIABLES
42: CALL INIVAR (CFORCE,LOCK,UDNSFT,TIME,ICLOCK,IC90C)
43: C ,TSHFT,NREC,BS,TB01GR,TB01GT,NGI,NGI0LD,ICYEND,VV0A,VANALG,
44: C HPWHLM,HPRAXM,HPTRANM,HPTR0CM,HPENGM,HPWHLP,HPRAXP,HPTRANP,
45: C HPT0CP,HPENGP,HPACC,
46: C ACT0RQ,PA0C,BF0RCER,PICLE,
47: C TAB1TR,TAB1SR,BADC,
48: C TIMMAX,TIMLEN,TIMAVG,PA0N,EA0N,SST0RC,TA0N,ESD0TO,VAR)
49: IC90C=0
50: ICYEND=0
51: INISRT=1
52: IREADY=0
53: IGB=1

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BUS SIMULATION PROGRAM

DAL

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54: TEST(I99)=0
55: TEST(3)=0
56: NFUEL=0
57: ISMAX=20
58: ISAVE=ISMAX+1
59: 10 CONTINUE
60: C----- BOOK KEEPING ROUTINES FOR POWER
61: CALL POWER(PASC,PASN,TASN,TAOC,T9IN,T9IC,T99N,T99C,ACTORQ
62: C ,SSTORQ,VV9A,BFORCE,BFORCEM,
63: C HPXHLM,HPXAXM,HPTRAXM,HPTQCM,HPENGM
64: C ,HPXALP,HPXAXP,HPTRAP,HPTSCP,HPENGP,HPACC)
65: C---- UPDATE SYSTEM CLOCK
66: ICLOCK=ICLOCK+1
67: TIME=ICLOCK*DT
68: C***** THIS IS THE TEST FOR SEEING IF THE TORQUE CONVERTER IS LOCKED UP
69: C***** LOCK=1 MEANS THE TC IS EITHER LOCKED LOCKING OR UNLOCKING
70: C***** ACCLOCK IS THE SPEED AT WHICH YOU LOCK THE TC
71: C***** IF THE ENGINE IS AT WIDE OPEN THROTTLE,
72: C***** ACCROIS IS THE SPEED TO LOCK UP IF NOT AT WIDE OPEN THROTTLE
73: IF (LOCK .GT. 0 .OR. VV9S .GT. ACCLOCK .OR.
74: C (TMAX.GT. SSTORQ+1. .AND.VV9S .GT. ACCROIS ))
75: CCALL LOCKUP(VV9S,TIME,LOCK,TA11SR,TA01TR)
76: C---- CALL TO ACCESS AND PROCESS IN ENGTQ
77: C---- ENGINE AND TORQUE CONVERTER
78: CALL ENGTQ(TA01TR,T911,T991EF,T901GR,T911GR,
79: C SSTORQ,ACTORQ,VVDF,VVDJ,VV9S,PASN,TA11SR,PASC,ICLOCK,
80: C ICLOCK1,TASN,SAON,ESDOT,BA6C,TAUC,LOCK )
81: IF (TEST(3))15,20,20
82: 15 CONTINUE
83: C---- AUTOMATIC DRIVER
84: CALL EPAVEL (TIME,VEPA,ICYEND,DELT)
85: CALL AUTSR (VV9S,T911,T991EF,T901GR,T911GR,TA01TR,VVDJ,
86: C VVDJ1,TA11SR,ACTORQ,PASN,DELT,VVDF,SSTORQ,B5,BFORCE,TIME,VEPA,
87: C TMAX)
88: 20 TO 25
89: 20 CONTINUE
90: C---- THROTTLE SETTING
91: CALL RIXON2(PASN,TS,TORG,MAP1)
92: SSTORQ=TORG*SCALEF
93: 25 CONTINUE
94: C---- HORSEPOWER
95: B5HP=SSTORQ*PASN/5252
96: C---- CALCULATE FUEL CONSUMPTION
97: CALL RIXON22(PASN,SSTORQ,PASFR,MAP3)
98: C---- DURING INITIALIZATION SKIP OTHER CALCULATIONS
99: IF (INISWT)30,30,60
100: 30 CONTINUE
101: ISAVE=ISAVE+1
102: IF (ISAVE=ISMAX)50,35,35
103: 35 ISAVE=0
104: NFUEL=NFUEL+1
105: IF (NFUEL=60)45,45,40
106: 40 NFUEL=60

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RJS SIMULATION PROGRAM

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107: 45 CONTINUE
108: FTIME(NFUEL)=ICLOCK*DT
109: ATGRQS(NFUEL)=SSTGRQ
110: ESPRED(NFUEL)=PAON
111: 50 CONTINUE
112: C---- TIRE GROWTH SUBROUTINE
113: CALL TGRIS(VVOS,T9IN,T9I1GR)
114: C---- GEAR SHIFT SUBROUTINE
115: CALL GRSHFT(TB01GR,ICLOCK,ISHIFT,T9IN,TMAX,UDNSFT,
116: C SSTGRQ,TB01GI,TAON)
117: C---- TRANSMISSION EFFICIENCY
118: CALL TREFF(TA9C,TB01GR,TB01EF,TB01GI,T9IN,T9IC)
119: C---- REAR AXLE EFFICIENCY
120: CALL RAEFF(T9IC,T9IN,T9I1GR,T90C,T9I1)
121: C---- VEHICLE DYNAMICS
122: CALL VEDYN(TB01GI,VVOS,BS,T90C,TB01GR,T9I1GR,VVAA
123: C ,VVDF,T9I1,VVDFBR,VVDMI,DELTAT,VVBAO,
124: C TVIMJ)
125: C---- JOINT PROBABILITY DISTRIBUTION
126: CALL PRDEN (SSTGRQ,PAON,NLT,NGT,IPDX)
127: ICYCLE=ICYCLE+1
128: C---- INTEGRATION SUBROUTINE
129: CALL INTGR(ICLOCK,ICLOCK1,NTIMEP,VVOS,
130: C VVFA,VVBAO,VVBSO,PAEFR,VVOD,FUELE,PAEFRQ)
131: C---- CHECK FOR END OF DRIVING CYCLE
132: NTIME=ICLOCK
133: NTIMEP=NTIME-ICLOCK
134: IF(ICYEND-1)55,90,90
135: C---- CHECK FOR OUTPUTS
136: 55 IF(NTIMEP-1OUT)10,85,85
137: 60 CONTINUE
138: C---- RESET INTEGRATION TIME COUNTER DURING INITIALIZATION
139: ICLOCK1=ICLOCK
140: C---- INITIALIZATION SECTION
141: IF(IREADY)65,65,75
142: 65 CONTINUE
143: C---- ENGINE IN STEADY STATE
144: RATE=ABS(ESDRT)
145: IF(RATE-EPST)70,70,10
146: 70 CONTINUE
147: IREADY=1
148: TEST(100)=-1.
149: 65 TO 10
150: 75 CONTINUE
151: IF(TEST(100))80,10,10
152: 80 CONTINUE
153: INISAT=0
154: TEST(3)=-1.
155: CALL INICR(PAON,SSTGRQ,PAEFR,INDIC,ICLOCK,TIME
156: C ,ICLOCK1,TB01EF,T9IN,TB0N,T90N,T9I1GR,VVOS,VVOD
157: C ,FUELE,EMISE,EMISE,ITICYC,ISHIFT,IGEAR,XHLGLD,
158: C VVDMI,DELTAT,T9IC,T9I1,LOCK,
159: C RETN(ICYCLE,NGTGLD,NGT,TB01GR,TB01GI,PAEFRQ,VVBAO

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BUS SIMULATION PROGRAM

VAL

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160: C ,VV9D,ISEC,IPDX,TIPMAX,TIMAVG,TIMLEN,HLT,NGT,VFPA,
161: C SS,T99C,VV9D,VVDFER,IVIMJ,TA9C,
162: C ICL9CK)
163: 85 CONTINUE
164: C---- OUTPUT SECTION
165: C***** DUE TO SPACE LIMITATIONS ONLY THE FIRST 140 CYCLES ARE RECORDED
166: CALL OUTVAR
167: INDIC=1
168: CALL OUTPUT (NLINE,PAGER,9BHP,VV9S,FUELE,
169: C VV9A,TIME,VVMA,PA9N,SST9RC,TAI1SR,TA01TR,TB01EF,
170: C T911,TB01GI,TA9N,TA9C,PA9C,VV9D)
171: AFUEL=0
172: ISAVE=IS*AX+1
173: ICL9CK=ICL9CK
174: IF (N.GT. 140) GOTO 110
175: XTIME(N)=TIME
176: XSST9R(N)=SST9RC
177: XACT9R(N)=ACT9RC
178: XP99C(N)=PA9C
179: XT99C(N)=TA9C
180: XT91C(N)=T91C
181: XT99C(N)=T99C
182: GEAR(N)=TB01GI
183: X9BHP(N)=SST9RC*PA9N/5252
184: ACCIP(N)=ACT9RC*PA9N/5252
185: FLYHP(N)=PA9C*PA9N/5252
186: CONHP(N)=(TA9C*PA9N/5252)*TAI1SR
187: DRSHHP(N)=((T91C*PA9N/5252)*(1.0/TB01GR))*TAI1SR
188: RAXHP(N)=((T99C*PA9N/5252)*(1.0/T911GR))*TAI1SR*(1.0/TB01GR)
189: N=N+1
190: 110 CONTINUE
191: G3 T9 10
192: 90 CONTINUE
193: C---- TERMINATION SECTION
194: CALL OUTVAR
195: END FILE 16
196: CALL OUTPUT (NLINE,PAGER,9BHP,VV9S,FUELE,
197: C VV9A,TIME,VVMA,PA9N,SST9RC,TAI1SR,TA01TR,TB01EF,
198: C T911,TB01GI,TA9N,TA9C,PA9C,VV9D)
199: CALL USFSUM(IPDX,ICYCLE,HLT,NGT,VV9D,FUELE,HPWHLP,
200: C HP9HP,HP9AXP,HP9AXM,HP9TRAP,HP9TRANM,HP9TCCP,
201: C HP9TCCY,HP9ENG,HP9ENGM,HP9ACC,TIME,
202: C XTIME,XSST9R,XP99C,XACT9R,XT99C,XT91C,XT99C,GEAR
203: C ,X9BHP,ACCIP,FLYHP,CONHP,DRSHHP,RAXHP)
204: READ SS,ISTOP
205: 95 FORMAT (I2)
206: IF(ISTOP)100,100,96
207: 96 CONTINUE
208: G3 T9 5
209: 100 CONTINUE
210: PAUSE
211: RETURN
212: END

```

3.3 PROGRAM SUBROUTINES

The overall program consists of the mainline program and the subroutines which are listed below and described in the following pages.

<u>SUBROUTINE NAME</u>	<u>SECTION NUMBER</u>	<u>PAGE</u>
AGNCON	3.3.1	36
ACCESS	3.3.2	38
AUTODR	3.3.3	41
ENGTRQ	3.3.4	47
EPAVEL	3.3.5	52
GRSHFT	3.3.6	52
INICON	3.3.7	58
INIGER	3.3.8	63
INIVAR	3.3.9	66
INTGRT	3.3.10	68
JPBSUM	3.3.11	72
LOCKUP AND LOCKCAL	3.3.12	76
MAPER	3.3.13	81
OUTCON	3.3.14	84
OUTPUT	3.3.15	86
OUTVAR	3.3.16	89
POWER	3.3.17	90
PRBDEN	3.3.18	92
PRTCON	3.3.19	95
RDEPA, EPACALC, EPAVEL	3.3.20	102
RAEFF	3.3.21	111
RIXON2, RIXON 22	3.3.22	121
TGG15	3.3.23	125
TQCONV, VELTERP	3.3.24	130
TREFF	3.3.25	138
VEDYN	3.3.26	152
VELTERP	3.3.27	162

The relationship of the subroutines to the mainline program is clearly shown in Figure 7, the mainline program flow chart. Program subroutines are described in the following subsections.

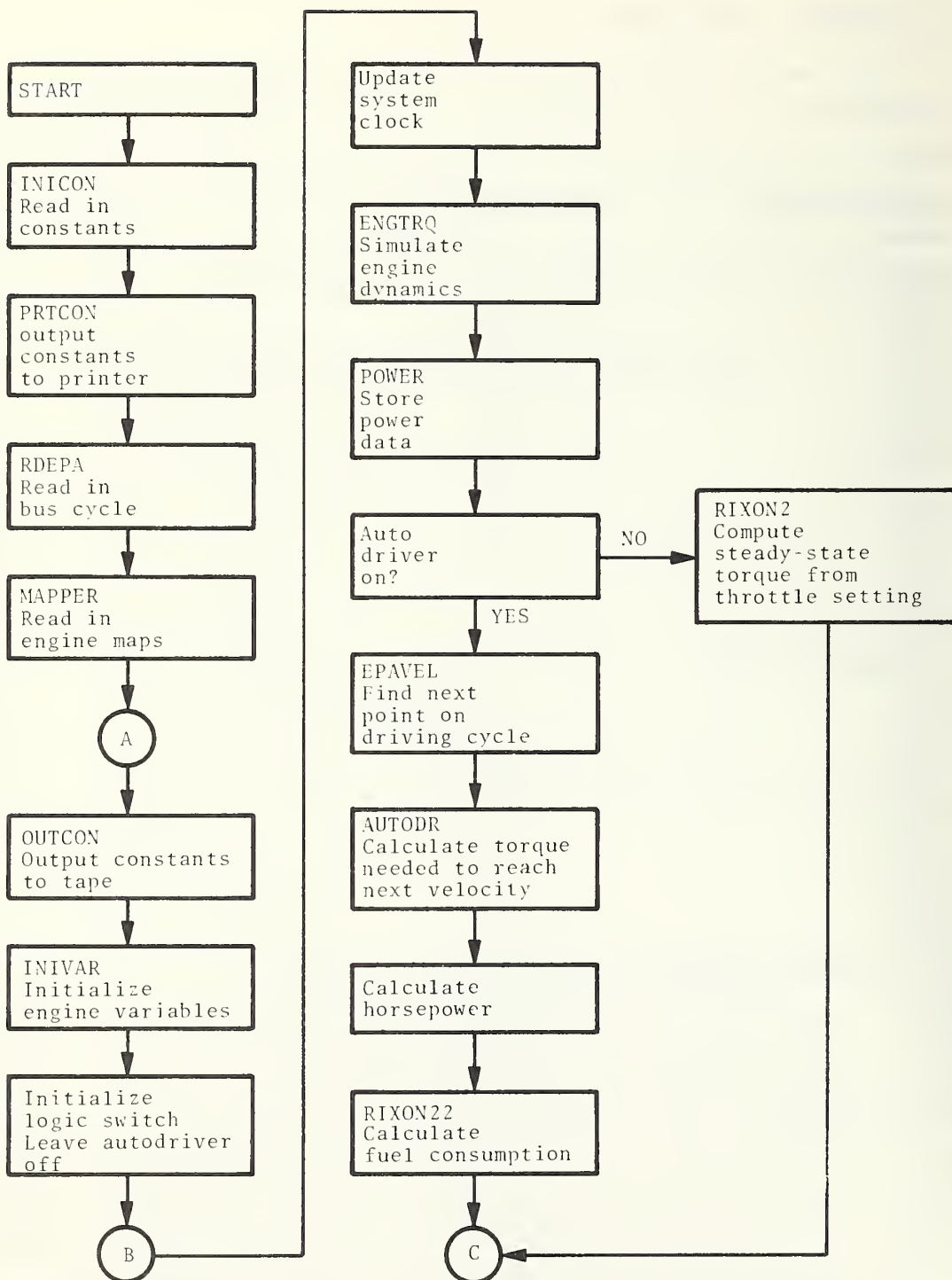


FIGURE 7. FLOW DIAGRAM FOR SIMULA

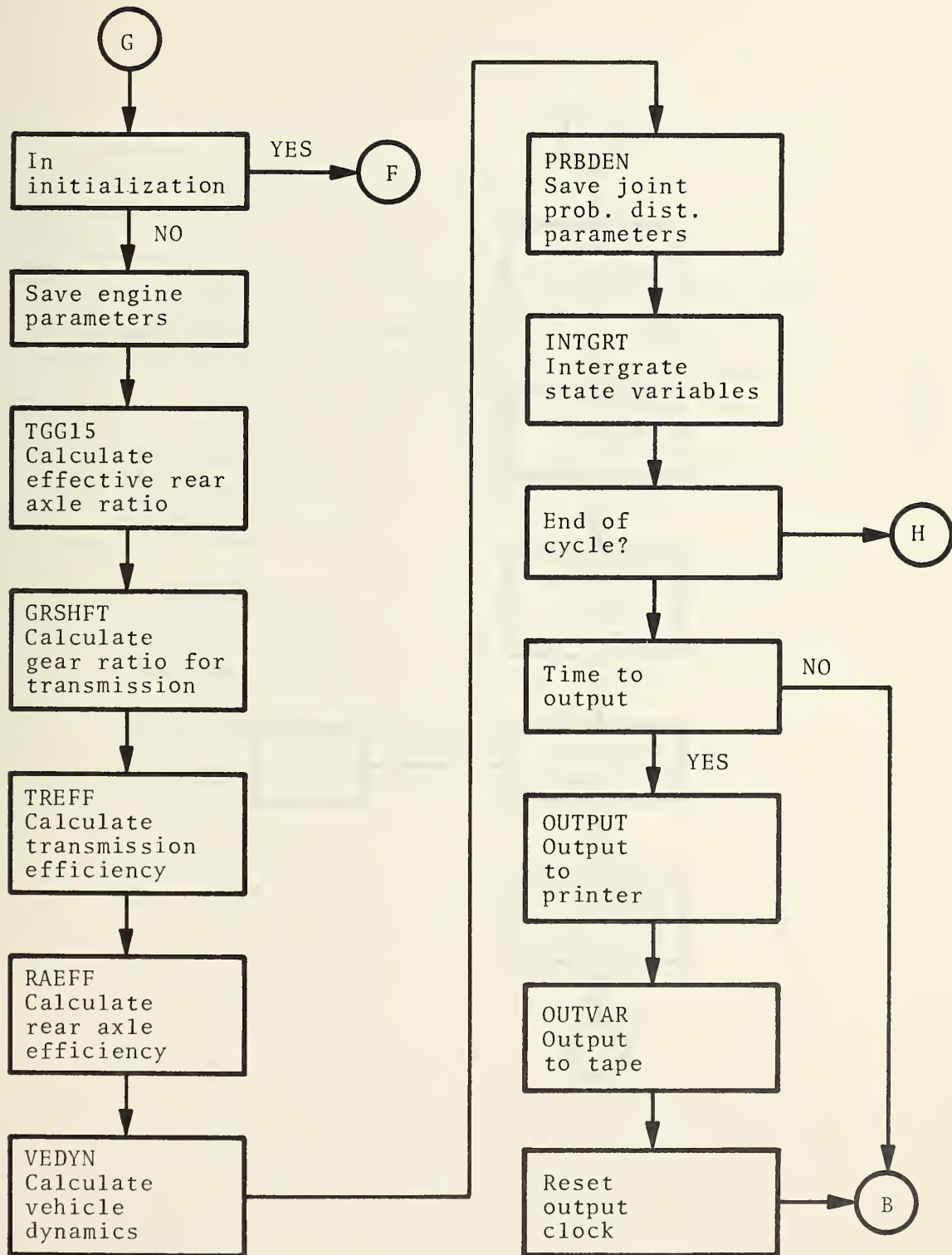


FIGURE 7. FLOW DIAGRAM FOR SIMULA (CONT'D)

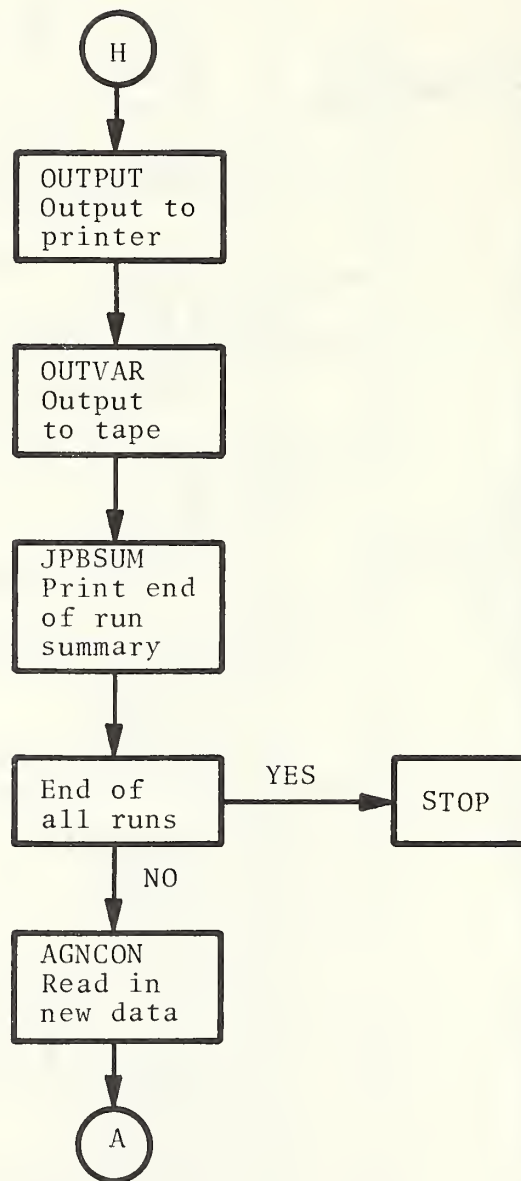


FIGURE 7. FLOW DIAGRAM FOR SIMULA (CONT'D)

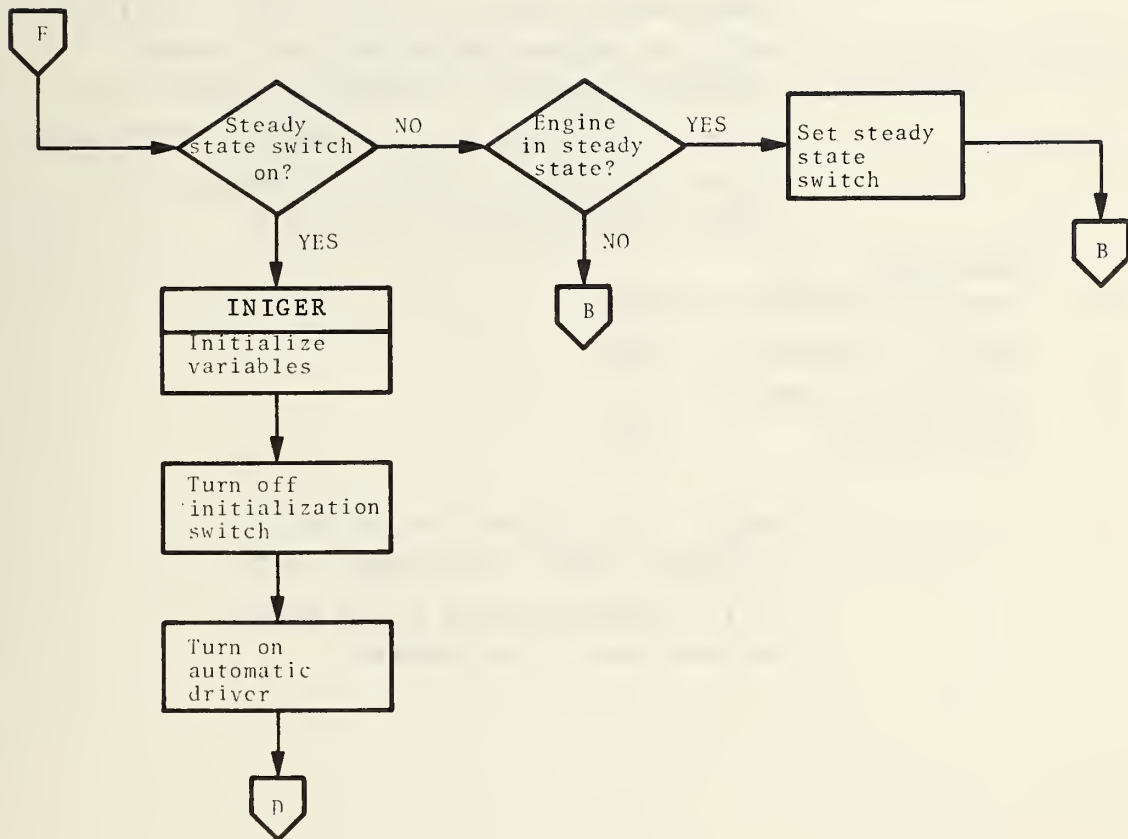


FIGURE 7. FLOW DIAGRAM FOR SIMULA (CONT'D)

3.3.1 Subroutine to Read Data - AGNCON

SUBROUTINE NAME: AGNCON

TYPE OF SUBROUTINE: Input

DESCRIPTION: This subroutine will be used when it is necessary to make a set of runs in which only one or two parameters are varied. AGNCON is written to read in those parameters which are being changed. The cards to be read in by AGNCON are added to the back of the standard data deck.

EQUATION: N/A

INPUT VARIABLES: N/A

OUTPUT VARIABLES: N/A

PROGRAM VARIABLES: N/A

FLOW CHART: N/A

NOTE: No listing for AGNCON IS provided here. Statements will vary depending upon which parameters are to be changed.

BUS SIMULATION PROGRAM

```
1: *                                     **** AGNCBN ****  
2:      SUBROUTINE AGNCBN  
3: C**** THIS SUBROUTINE IS USED TO CHANGE THE BUS OR CYCLE CHARACTER  
4: C**** WITHOUT HAVING TO REINITIALIZE THE ENTIRE SYSTEM  
5:      10 CONTINUE  
6:      RETURN  
7:      END
```

3.3.2 Accessory Load Subroutine - ACCESS

SUBROUTINE NAME: ACCESS

TYPE OF SUBROUTINE: System computation

DESCRIPTION: This subroutine calculates accessory load in foot-pounds given the engine speed in revolutions per minute (RPM's).

MODELING: The accessory loads are stored at 200 RPM intervals. Figure 8 illustrates a typical accessory load curve from which the points are taken. Linear interpolation is used for non-node points.

EQUATION: $T_A = g_4 (N_E)$

INPUT VARIABLES: PAON - Engine speed

OUTPUT VARIABLES: ACTORQ - Accessory torque loss

OTHER VARIABLES: ACLOAD(10) - Accessory load table

PIDLMIN - Minimum engine speed table good for

PIDLMAX - Maximum engine speed table good for

PROGRAM VARIABLES: I - Low index
II - High index

FLOW CHART: N/A

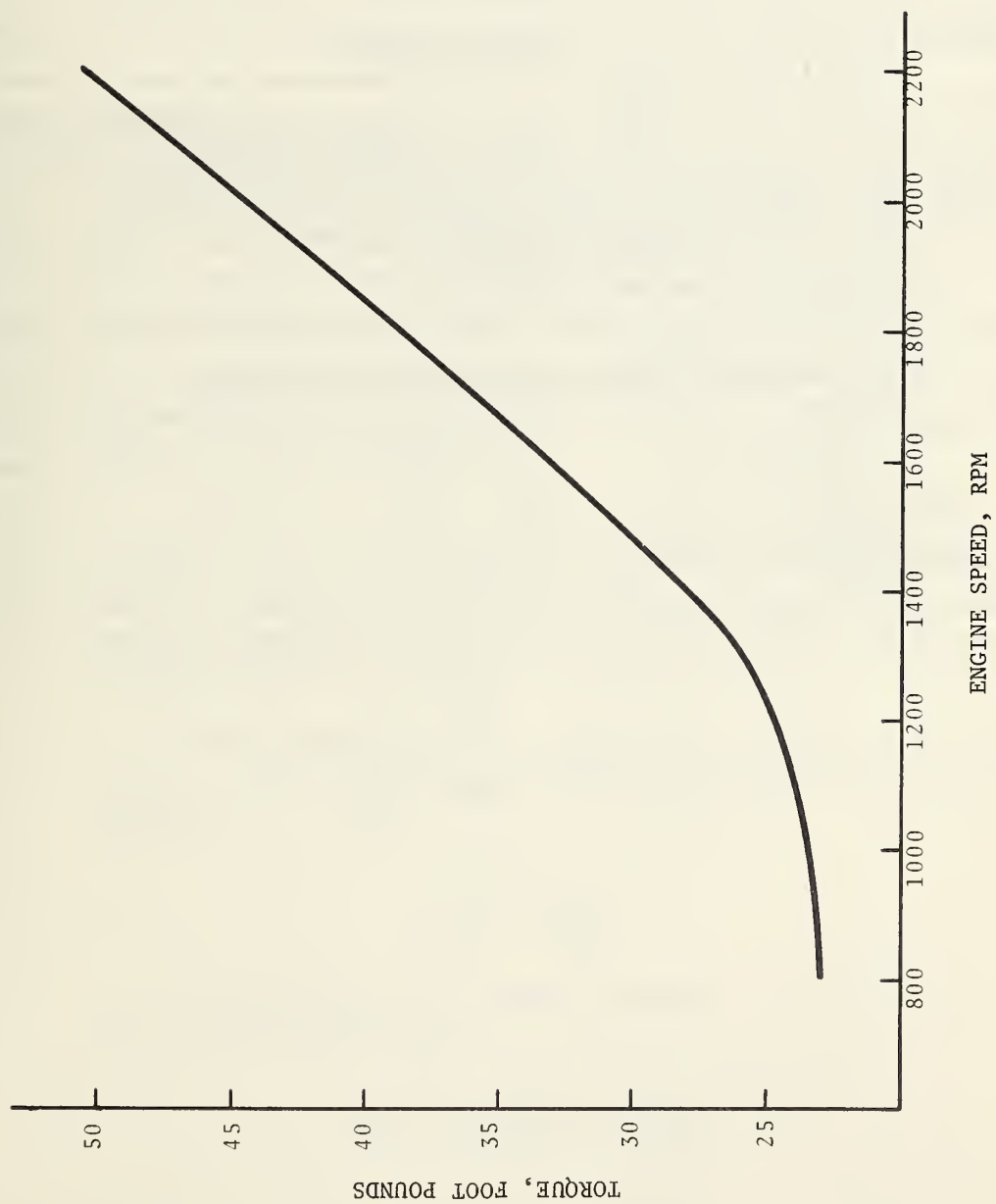


FIGURE 8. ACCESSORY TORQUE AS A FUNCTION OF ENGINE SPEED

BUS SIMULATION PROGRAM

DATE

```
1: *          **** ACCESS ****
2: SUBROUTINE ACCESS(PA8N,ACTORC)
3: C----- COMPUTE ACCESSORY LOAD
4: C***** THIS SUBROUTINE DETERMINES THE ACCESSORY LOAD THAT IS USED BY THE
5: C***** BUS FOR A GIVEN ENGINE SPEED. A LINEAR INTERPPATION METHOD IS U
6: C***** PIDLMIN AND PIDLMAX ARE THE BOUNDS OF THE ARRAY AKCESS
7: C***** WHICH HOLDS THE ACCESSORIES IN 200 RPM INCREMENTS
8: C-----RICK HUDSON 9/21/76 FOR THE BUS
9: COMMON /ACCESS/ ACL8AD(10),PIDLMIN,PIDLMAX
10: IF (PA8N .LT. PIDLMIN) G8T8 10
11: IF (PA8N .GT. PIDLMAX) G8T8 20
12: I=PA8N/200-3
13: II=I+1
14: REM=PA8N-(I+3.)*200.
15: ACT8RC=ACL8AD(I) + REM*(ACL8AD(II)-ACL8AD(I))/200.
16: G8T8 999
17: 10 CONTINUE
18: ACT8RC=ACL8AD(1)
19: G8T8 999
20: 20 CONTINUE
21: ACT8RC=ACL8AD(10)
22: 999 CONTINUE
23: RETURN
24: END
```

3.3.3 Automatic Driver - AUTODR

PROGRAM NAME: AUTODR

TYPE OF SUBROUTINE: System computation

DESCRIPTION: This subroutine specifies the steady state torque required to follow a given velocity profile.

MODELING:

This subroutine is the controller for a closed loop feedback control system in which the vehicle velocity is the controlled variable (see Figure 9]. The "error" is the difference between the actual vehicle velocity and the velocity specified at the next cycle point. The automatic driver determines the engine torque required to overcome accessory load, friction and acceleration forces to reach the next cycle velocity.

Subroutine EPAVEL supplies the automatic driver (AUTODR) with the velocity required at the next specified point in time and the time difference between that time and the current time. The cycle velocities are specified at one second intervals.

The automatic driver calculates the acceleration required to reach the next cycle point within the time difference,

$$A_R = \frac{V_i - V}{\Delta t}$$

The steady state torque required of the engine to provide this acceleration is

$$T_{SS} = \frac{A_R M_I + R}{K} + T_A$$

K is the torque multiplication factor from the engine to the rear wheels. Its value is determined by using the gear ratios and efficiencies calculated in the previous iteration (see Figure 4). K will become zero at zero driveshaft torque because the driveshaft and rear axle efficiencies are zero. This means very large engine torques would be required as K approaches zero. To prevent this, a minimum transmission and rear axle efficiency of 0.8 is assumed when calculating K. A similar problem exists if Δt approaches zero in the acceleration calculation. To prevent this EPAVEL supplies the next required velocity when Δt becomes less than .1 second.

To prevent the engine from attempting to overcome the vehicle rolling resistance at idle, the resistive force of the vehicle is set to 0 when there is no vehicle speed.

The subroutine also ensures that the limits of the engine are not exceeded. It determines the maximum engine torque and the minimum engine torque possible by checking the wide open and closed throttle torques of the engine at the given speed. It supplies only the maximum engine torque if the maximum torque is exceeded, or calculates the required braking force when the minimum engine torque is not enough to slow the vehicle as rapidly as required.

EQUATIONS:

$$1) \quad A_R = \frac{V_i - V}{\Delta t} \quad \text{where: } \Delta t \geq 0.1$$

$$2) \quad K = \frac{TR \cdot \eta_{RA} \cdot \eta_{TR} \cdot GR_{RA} \cdot GR_{TR} \cdot GR_{BG}}{R_T}$$

$$\text{where: } \eta_{RA} \geq 0.8$$

$$\eta_{TR} \geq 0.8$$

$$3) \quad M_I = (M_I)_V + J_E \cdot \frac{SR \cdot GR_{RA} \cdot GR_{TR} \cdot GR_{BG}^2}{RT}$$

where: $(M_I)_V$ is the inertial mass of the vehicle as calculated in the vehicle dynamics subroutine (VEDYN). It does not include the rotary inertia of the engine.

$$4) \quad T_{SS} = \frac{A_R \cdot M_I + R}{K} + T_A$$

$$5) \quad F_B = \frac{(T_{SS})_{\min} - (T_{SS})_{\text{required}}}{K}$$

INPUT VARIABLES:

<u>Variable Name</u>	<u>Symbol</u>	<u>Description</u>
VEPA	V_i	Required cycle velocities
VVOS	V	Vehicle velocity
DELT	Δt	Time difference between next cycle point and current time
T9I1	η_{RA}	Rear axle gear efficiency
TB01EF	η_{TR}	Transmission gear efficiency
TB01GR	GR_{TR}	Transmission gear ratio
T9I1GR	GR_{RA}	Equivalent rear axle gear ratio
BGRT10	GR_{BG}	Bevel Gear Ratio
TA0N	N_{CO}	Converter output speed
PA0N	N_E	Engine speed
LOCK		Indicates if torque converter is locked
BAOC		Converter input speed

OUTPUT VARIABLES:

PA0C	T_E	Engine output torque
TA0C	T_{CO}	Converter output torque

OTHER PROGRAM VARIABLES:

TAI1SR	SR	Speed ratio
TAI3KI	K_I	Input size factor
TAI3IK	$1/K_I^2$	Inverse input size factor squared
TA01TR	TR	Torque ratio

CONSTANTS IN MEMORY:

AWAY(20,30	Column one hold speed ratio column two the torque ratio and column three the inverse size factor squared
BGRT10	Bevel Gear Ratio

<u>Variable Name</u>	<u>Symbol</u>	<u>Description</u>
VVDF	R	Vehicle road load
TA01TR	TR	Converter torque ratio
TAI1SR	SR	Converter speed ratio
VVDMI	(M_I)	Inertial vehicle mass
ACTORQ	T_A^V	Accessory torque loss
PA0N	N_E	Engine speed
TMAX	$(T_{SS})_{MAX}$	Maximum steady state engine torque
SST	$(T_{SS})_{MIN}$	Minimum steady state engine torque

OUTPUT VARIABLES:

SSTORQ	T_{SS}	Steady state engine torque
BS	B_S	Brake setting
VVDJ	M_I	Inertial vehicle mass including engine rotary inertia
BFORCE	F_B	Braking force

VARIABLES WHICH MUST BE STORED IN MEMORY:

VVI2BR	K_B	Brake constant
--------	-------	----------------

RIE	J_E	Rotary engine inertia
VVIDRR	R_T	Tire Radius

NOTE: R_T is considered constant only because the effect of tire growth is considered as an effective change in rear axle ratio (see TGG15).

OTHER PROGRAM VARIABLES:

T9ID	η_{RA}	Dummy rear axle efficiency variable
TB01ED	η_{TR}	Dummy transmission efficiency variable
AEPA	A_R	Acceleration required to reach next cycle velocity
GR	GR	Gear ratio from engine to rear wheels
TQMULT	K	Total driveline torque multiplication factor

SUBROUTINES REQUIRED:

RIXON2 (PA0N, TIDLE, SST, MAP1)

BUS SIMULATION PROGRAM

DATA

```

1: *
2: SUBROUTINE AUTOBR (VVBS,T911,TB91EF,TB91GR,T911GR,TAB1TS,VVDJ,
3: C VVDM,TAT1SR,ACTGR,PAGN,DELT,VVDF,SSTGR,BS,BFORCE,TIME,VEPA,
4: C TMAX)
5: C-----DAN KAPellen, ALGORITHM BY N. BEACHLEY, 1-8-74
6: C----- RICK HUDSON 1/77 FOR THE BUS
7: C----- SUBROUTINE TO ANTICIPATE ENGINE STEADY STATE TORQUE AND BRAKE
8: C----- SETTING REQUIRED TO FOLLOW A GIVEN DRIVING CYCLE.
9: COMMON /BGEAR/ BGRTIO
10: COMMON /ENGINE/ SCALEF, TIDLE, EVS, TS
11: COMMON /INERTIA/ RIE, RIEINV
12: DIMENSION MAP1(55,17), MAP3(17,17)
13: COMMON /MAPS/ MAP1, MAP3
14: COMMON /MASS/ VVILFR, VVI1CD, VVI1RF, VVIMI, VVI2BR, VVIM, VVIMDR,
15: C VVISWB, VVISH, VVIAMX, VVIAS
16: COMMON /TIRE/ VVIDRR, VVIFUM, VVIFUS, VVI1CF
17: C----- VEPA IS CALCULATED IN EPAVEL
18: *
19: AEPA=(VEPA-VVBS)/DELT
20: IF (VEPA .LE. 0.1 .AND. VVBS .LE. 0.1) VVDF = 0.0
21: *
22: C----- T91D AND TB91ED ARE SET TO .8 MINIMUMS TO AVOID DIVISION BY ZERO
23: T91D=T911
24: IF (T91D .LT. 0.8) T91D = 0.8
25: *
26: TB91ED=TB91EF
27: IF (TB91ED .LT. 0.8) TB91ED = 0.8
28: *
29: C----- DETERMINE TORQUE MULTIPLICATION FROM ENGINE TO REAR WHEELS,
30: C----- GEAR RATIO, REAR AXLE RATIO, BEVEL GEAR RATIO IN DENOMINATOR
31: GR=VVIDRR/(TB91GR*T911GR*BGRTIO)
32: TGMULT=(TAT1SR*T91D*TB91ED)/GR
33: C----- DETERMINE TOTAL EQUIVALENT MASS OF VEHICLE INCLUDING ROTARY INERT
34: C OF DRIVE TRAIN AND ENGINE).
35: VVDJ=VVDM+RIE*((TAT1SR/GR)**2)/32.1739
36: C----- ANTICIPATE THE STEADY STATE ENGINE TORQUE REQUIRED TO ACHIEVE THE
37: C----- NEXT CYCLE VELOCITY.
38: SSTGR=(AEPA*VVDJ*1.4667+VVDF)/TGMULT+ACTGR
39: IF (AEPA .LT. 0.05 .AND. PAGN .LT. 950.0)
40: 1 SSTGR = SCALEF*(SSTGR+(950.0-PAGN)/RIEINV)
41: C----- FOR POSITIVE STEADY STATE TORQUE CHECK THAT ENGINE IS NOT REQUIRED
42: C----- TO EXCEED ITS MAXIMUM TORQUE CAPABILITY.
43: CALL FIXGR2(PAGN,100.,TMAX,MAP1)
44: TMAX=TMAX*SCALEF
45: IF (SSTGR .GT. TMAX) SSTGR=TMAX
46: C BS=0.
47: C BFORCE=0.
48: C GOTO 900
49: C----- DETERMINE MAXIMUM NEGATIVE STEADY STATE TORQUE POSSIBLE FOR GIVEN
50: C----- ENGINE SPEED.
51: CALL FIXGR2(PAGN,TS,SST,MAP1)
52: SST=SST*SCALEF
53: IF (SSTGR .LT. SST) CONTINUE

```

BUS SIMULATION PROGRAM

```

54:      C      BFORCE=(SST-SSTORG)*TGMULT;
55:      C      BS=BFORCE/VVI2BR;
56:      C      SSTORG=SST;
57:      C      GOTO 900
58: C----- TORQUE REQUIRED AT THE ENGINE AND THE DECELERATION TORQUE PRO
59: C----- BY THE ENGINE TIMES THE TORQUE MULTIPLICATION.
60: C----- DETERMINE THE REQUIRED BRAKE FORCE AS THE DIFFERENCE BETWEEN
61: C----- THE BRAKE SETTING IS THE REQUIRED BRAKING FORCE DIVIDED BY TH
62: C----- BRAKE CONSTANT.
63: **** IF(SSTORG .LT. TMAX .AND. SSTORG .GT. SST) THEN
64:      SS=0.
65:      BFORCE=0.
66: 900  CCONTINUE
67:      RETURN
68:      END

```

3.3.4 Integration of Engine Speed - ENGTRQ

SUBROUTINE NAME: ENGTRQ

TYPE OF SUBROUTINE: System Computation

DESCRIPTION: This subroutine calculates engine accelerations based on needed flywheel torque, accessory torque and steady state torque. If the torque converter is locked up the engine speed is calculated directly based on gear ratios and efficiencies from the previous iteration. After the engine speed is calculated the input speed for the torque converter is determined. See Figure 10.

MODELING: A second order integration scheme is used. This subroutine is used in the all-digital program only.

EQUATION: For locked up torque converter

$$TM = FG_{TR} * GR_{RA} * GR_{BG} * TR_{TQ} * \eta_{RA} * TA/RT$$
$$N_{VN} = (T_S - T_A - F_D/TM) * TM/F_B * DT + N_{VO}$$
$$N_E = N_{VN} * GR_{TR} * GR_{RA} * GR_B / (SR_{TQ} * RT)$$

For unlocked torque converter

$$\Delta N_E = \frac{T_{SS} - T_A - T_E}{J_R}$$
$$N_E = N_E + (\Delta N_{E \text{ OLD}} + \Delta N_{E \text{ NEW}}) * (T_P - T_{PO}) * DT/2$$

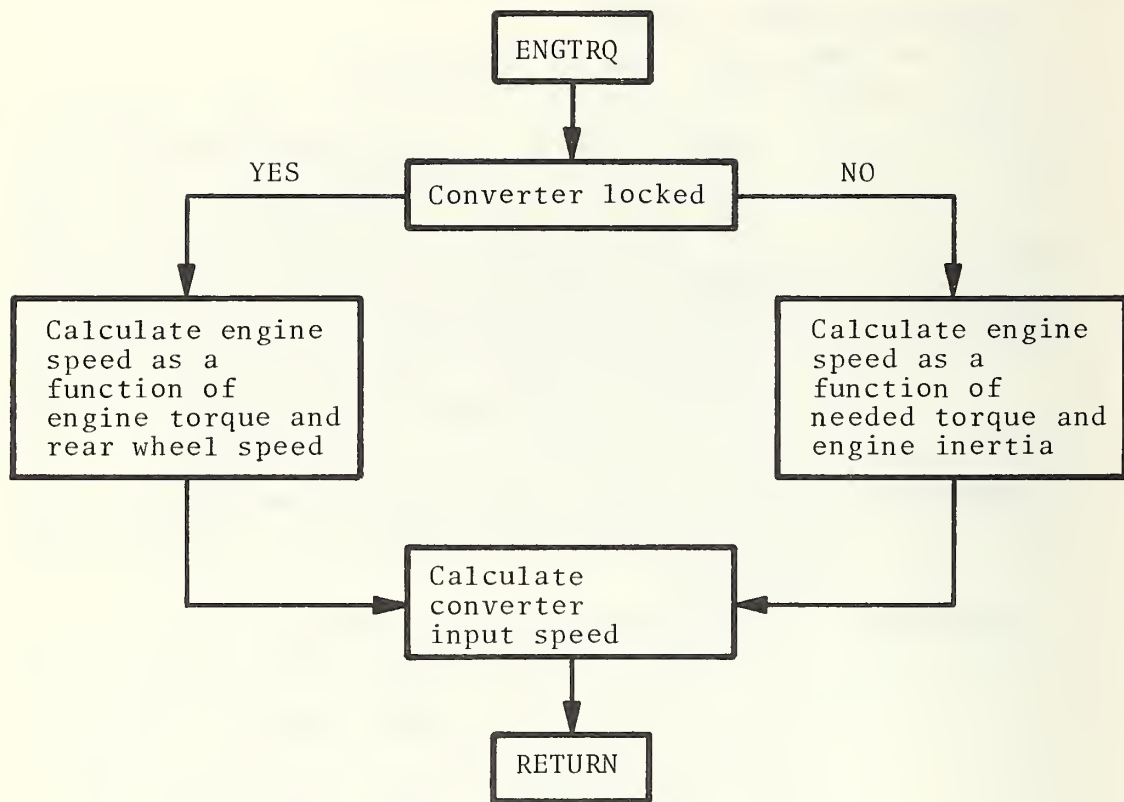


FIGURE 10. ENGTRQ FLOW DIAGRAM

<u>Variables Used</u>	<u>Symbol</u>	<u>Meaning</u>
<u>Input</u>		
ACTORQ	T_A	Accessory Torque
BAON	N_{CI}	Converter input speed
ICLOCK	T_P	Present time pulse
ICLOCK 1	T_{PO}	Past Time pulse
LOCK		Indicates if converter is locked
PAOC	T_E	Engine output torque
PAON	N_E	Engine speed
SSTORQ	T_{SS}	Engine torque
TAI1SR	SR	Speed ratio
TAO1TR	TR	Torque ratio
TAON	T_{CO}	Converter output speed
TBO1EF	η_{TR}	Transmission gear efficiency
TBO1GR	GR_{TR}	Transmission gear ratio
T9I1	η_{RA}	Rear axle efficiency
T9I1GR	GR_{RA}	Rear axle gear ratio
VVDF	F_D	Total drag force
VVDJ		
VVOS	V	Vehicle velocity
<u>Output</u>		
BAOC	T_{CI}	Converter input torque
BAON	N_{CI}	Converter input speed
PAOC	T_E	Engine output torque
PAON	N_E	Engine speed
TAI1SR	SR	Speed ratio
TAO1TR	TR	Torque ratio
TAOC	T_{CO}	Converter output torque

<u>Variable Used</u>	<u>Symbol</u>	<u>Meaning</u>
<u>Local Variables</u>		
ESDOT	ΔN_E	Engine acceleration
ESDOTO	ΔN_{EP}	Previous Engine acceleration
<u>Constants Used</u>		
BGRT10	GR_{BG}	Level gear ratio
DT	ΔT	Length of time pulse
RIEINV		Inverse engine inertia
VV1DRR	W_R	Wheel radius

BUS SIMULATION PROGRAM

D2

```

1: *                                     *** ENGTRO ***
2: SUBROUTINE ENGTRO(TAO1TR,T9I1,TB91EF,TB91GR,T9I1GR,
3: C SSTORQ,ACTORQ,VVDF,VVDJ,VVDS,PAGN,TAI1SR,PAOC,ICLOCK,
4: C ICLCK1,TA9N,BAGN,ESDOT,BAGC,TA9C,L9CK)
5: C---- R-TRADTKE 3/5/74
6: C**** RICK HUDSON 1/77 FOR THE BUS
7: COMMON /GGEAR/ BORT10
8: COMMON /INERTIA/ RIE,RIEINV
9: COMMON /TIRE/ VVIORR,VVIFUM,VVIFUS,VVILCF
10: COMMON /TIME/ DT
11: *
12: C *****14.00656=5280/60*2*PI
13: C**** ACTORS TORQUE USED BY THE ACCESSORIES
14: C**** BAC CONVERTER INPUT TORQUE
15: C**** BAGN TORQUE CONVERTER INPUT SPEED
16: C**** BORT10 BEVEL GEAR RATIO
17: C**** BEVEL GEAR IS LOCATED BETWEEN THE ENGINE AND THE IMPELLER OF TI
18: C**** TORQUE CONVERTER
19: C**** L9CK INDICATES IF THE LOCK ON THE CONVERTER IS ON
20: C**** PAC ENGINE TORQUE AT THE FLYWHEEL
21: C**** PAGN ENGINE SPEED
22: C**** TAI1SR CONVERTER SPEED RATIO
23: C**** TAB1TR CONVERTER TORQUE RATIO
24: *
25: CALL ACCESS (PAGN,ACTORQ)
26: CALL TCONV(L9CK,PAOC,ACTORQ,TAB1TR,
27: C TAI1SR,TA9N,BAGN,BAGC,TA9C)
28: IF (L9CK .GT. 1)
29: C TM=(TAB1TR*T9I1+TB91EF+TB91GR+T9I1GR*BORT10)/VVIORR
30: C ACCL=(SSTORQ-ACTORQ-VVDF/TH)*TM/(VVDJ*1.4667)
31: C EVVDS=ACCL*DT+VVDS
32: C PAGN= EVVDS*TB91GR+T9I1GR*BORT10*14.00656/(TAI1SR*VVIORR)
33: C GOTO 900
34: ESDOT=(SSTORQ-ACTORQ-PAC)*RIEINV
35: PAGN=PAGN+(ESDOT+ESDOT0)*(ICLOCK-ICLK1)*DT/2,
36: ESDOT0=ESDOT
37: 900 CONTINUE
38: BAGN=PAGN/BORT10
39: 999 CONTINUE
40: RETURN
41: END

```

3.3.5 Subroutine to Obtain Target Velocity - EPAVEL

SUBROUTINE NAME: EPAVEL

DESCRIPTION: See RDEPA - Section

3.3.6 Gearshift - GRSHFT

SUBROUTINE NAME: GRSHFT

TYPE OF SUBROUTINE: System Computation

DESCRIPTION: The gear shift subroutine determines the transmission gear number and gear ratio as a function of the driveshaft speed.

MODELING: In this simulation the driveshaft speed at which shift occurs is stored in memory.

This is done in the initialization subroutine (INICON). The shifting criteria can be specified for 2 or 3 gears.

The gear shift subroutine retrieves driveshaft speeds at which upshift and downshift will occur.

The block diagram in Figure 11 shows the general procedure for determining the gear ratio.

When a shift takes place the program changes the gear ratio linearly between gears for a period of 1/2 second to simulate slipping of the clutch bands. To prevent the transmission from upshifting and downshifting continuously, some form of hysteresis must also be introduced. This is accomplished by holding the transmission in the new gear for another second before allowing it to shift again.

The program returns the converter turbine speed for use in calculating the speed ratio.

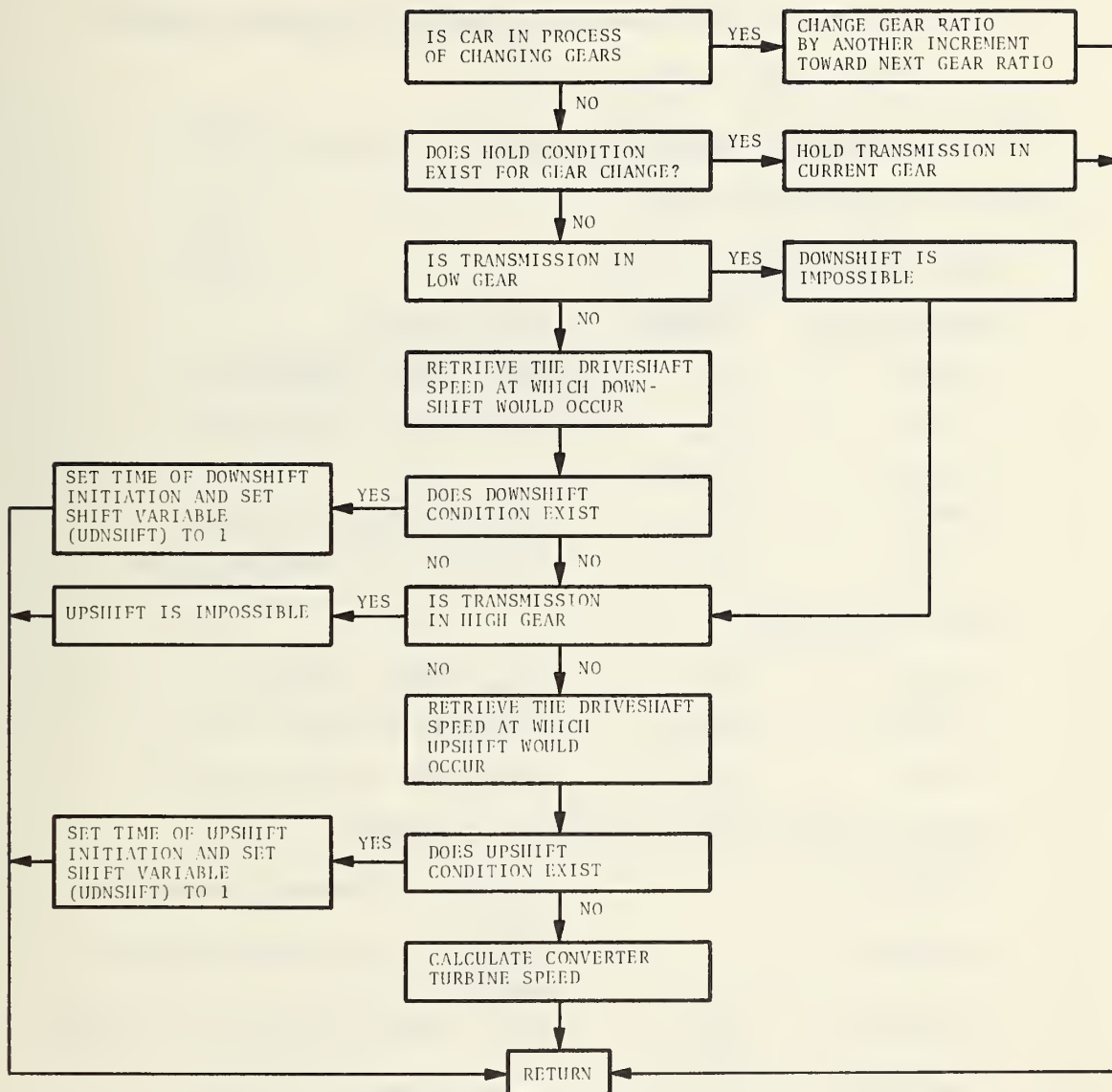


FIGURE 11. GRSFT FLOW DIAGRAM

EQUATIONS:

1) Equation to determine gear ratio during gear change.

$$GR_{TR} = GR_i + (GR_{i+1}) \cdot \frac{t_N}{t_s}$$

2) Equation to determine converter turbine speed

$$N_{CO} = N_{PS} * GR_{TR}$$

INPUT VARIABLES:

<u>Program Name</u>	<u>Symbol</u>	<u>Description</u>
TB01GI	GI	Gear index (number)
T9IN	N_{DS}	Driveshaft speed
ICLOCK	Time	
TMAX	T_{MAX}	Maximum engine torque
SSTORQ	T_{SS}	Steady State engine torque

OUTPUT VARIABLES

TB01GI	GI	Gear index (number)
TB01GR	GR_{TR}	Transmission gear ratio
TAON	N_{CO}	Converter turbine speed

VARIABLES WHICH MUST BE STORED IN MEMORY:

GRMIN(I)		Minimum driveshaft speed for Gear I
GRMAX(I)		Maximum driveshaft speed for Gear I
TBC1CI(I)	GR_i	Gear ratios for gears 1 through i
IBC1GI(I)	GI_i	A bookkeeping variable to determine when bus is in low and high gear. 1 = low gear, 3 = high gear, 2 = intermediate gears
TBDTMS	t_s	Time allowed for gear shift
TBDTH	t_h	Time allotted for shift hysteresis

OTHER PROGRAM VARIABLES:

I	i	Integer form of gear index
UDNSFT		Integer indicating if shift is in progress
IGEAR	<u>+1</u>	Indicates pushift or downshift
TBDTIN	t_N	Time elapsed since gear shift
ISHIFT		Time at which shift is initiated

TRANSMISSION SHIFT SCHEDULE

<u>UPSHIFT</u>	<u>DRIVESHAFT RPM</u>
----------------	-----------------------

1-2	920
-----	-----

2-3	1580
-----	------

DOWNSHIFT

3-2	1520
-----	------

2-1	550
-----	-----

```

1: * **** GRSHFT ****
2: SUBROUTINE GRSHFT(TB91GR,ICLOCK,ISHIFT,T9IN,TMAX,UDNSFT,
3: C SSTGRQ,TB01GI,TAGN)
4: C***** RICK HUDSON 1/77
5: C***** THIS SUBROUTINE CALCULATES THE GEAR RATIO AS A FUNCTION OF THE
6: C***** DRIVESHAFT SPEED
7: C*****
8: C---- TB91GI- CURRENT GEAR IN WHICH VEHICLE IS OPERATING.
9: C---- T9IN-DRIVESHAFT SPEED (RPM).
10: C---- ICLOCK-TIME. (ONE-HUNDRETHS OF A SECOND).
11: C-----OUTPUT VARIABLES-----
12: C---- TB91GI-NEW GEAR INDEX IF VEHICLE CHANGES GEARS.
13: C---- TB91GR-TRANSMISSION GEAR RATIO.
14: C-----INPUT VARIABLES-----
15: C---- ISHIFT- TIME AT WHICH SHIFT IS INITIATED.
16: C-----PROGRAM CONSTANTS-----
17: C***** GRMIN-MINIMUM DRIVESHAFT SPEED FOR THE INDEXED GEAR
18: C***** GRMAX-MAXIMUM DRIVESHAFT SPEED FOR THE INDEXED GEAR
19: C***** GRMAXCR-MAXIMUM DRIVESHAFT SPEED FOR THE INDEXED GEAR IF THE BUS IS
20: C***** IN CRUISE MODE
21: C----- TBC1GR(I)- GEAR RATIOS FOR GEARS 1 THROUGH I.
22: C---- TBC1GI(I)- BOOKKEEPING VARIABLE TO DETERMINE WHEN CAR IS IN HIGH
23: C---- AND LOW GEAR. USEFUL FOR TRANSMISSIONS WITH MORE THAN 3 GEARS.
24: C---- TBDTMS-TIME ALLOWED FOR GEAR SHIFT.
25: C-----OTHER PROGRAM VARIABLES-----
26: C---- TBDTH-DELAY TIME AFTER SHIFT BEFORE ANOTHER SHIFT CAN OCCUR.
27: C***** UDNSFT UPSHIFT OR DOWNSHIFT INDICATOR
28: C---- TBDTIN-TIME ELAPSED SINCE GEAR SHIFT)
29: C*****
30: COMMON /SHIFTER/ GRMAX(3),GRMIN(3),GRMAXCR(3)
31: COMMON /SFTIME/ TBDTMS,TBDTH
32: COMMON /TGRTI9/ TBC1GR(10),GR1
33: INTEGER UDNSFT
34: I=TB91GI
35: II=TB91GI-UDNSFT
36: C---- CALCULATE TIME ELAPSED SINCE LAST GEAR SHIFT.
37: TDTIN=ICLOCK-ISHIFT
38: C---- DETERMINE IF VEHICLE IS IN PROCESS OF CHANGING GEARS.
39: IF(TBDTIN-TBDTMS)10,10,11
40: C-----IF CHANGE IS IN PROCESS, CALCULATE NEW GEAR RATIO BASED ON TIME.
41: 10 TB91GR=TBC1GR(I)+(TBC1GR(II)-TBC1GR(I))*TBDTIN/TBDTMS
42: GOTO 999
43: 11 CONTINUE
44: C***** CHECK TO SEE IF UPSHIFT CONDITIONS EXIST
45: IF (T9IN.GT. GRMAX(I).OR. (T9IN.GT. GRMAXCR(I).AND. TMAX.GT.
46: C SSTGRQ+1.)) GOTO 50
47: ITEMP=I-1
48: C***** CHECK TO SEE IF WE ARE IN LOW ALREADY
49: IF (ITEMP.LE. 0) GOTO 90
50: C***** CHECK TO SEE IF DOWNSHIFT CONDITIONS EXIST
51: IF (T9IN.LT. GRMIN(I)) GOTO 60
52: C***** NO SHIFTING DURING THIS ITERATION
53: UDNSFT=0

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54:      GET 95
55:      50 CONTINUE
56: C      UPSHIFT
57:      ISHIFT=ICLOCK
58:      TB01G1=I+1
59:      UDNSFT=1
60:      GET 95
61:      60 CONTINUE
62: C      DOWNSHIFT
63:      ISHIFT=ICLOCK
64:      TB01G1=I-1
65:      UDNSFT=-1
66:      GET 95
67:      90 CONTINUE
68:      TB01GR=TB01GR(I)
69:      GET 999
70:      95 CONTINUE
71:      TB01GR=TB01GR(I)
72:      999 CONTINUE
73:      TASN=T9IN*TB01GR
74:      RETURN
75:      END
```

3.3.7 Subroutine to Initialize Maps and Tables - INICON

SUBROUTINE NAME: INICON

TYPE OF SUBROUTINE: INITIALIZATION

DESCRIPTION: This subroutine reads in maps and tables needed by the system computation routines. It reads in all constants that are required and calculates other constants as necessary. It also calculates acceleration limits of the vehicle, accounting for weight transfer.

EQUATIONS: Maximum vehicle acceleration accounting for weight transfer without tire slippage:

$$A_{MAX} = f_M \cdot M_{DR} \cdot W_B / (M \cdot (W_B - A_{MIN} \cdot H))$$

Maximum vehicle acceleration with tires slipping:

$$A_{MAXS} = f_S \cdot M_{DR} \cdot W_B / (M \cdot (W_O - A_{MIN} \cdot H))$$

INPUT VARIABLES: S/L

OUTPUT VARIABLES: S/L

OTHER VARIABLES: N/A

PROGRAM VARIABLES: N/A

FLOW CHART: N/A

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1: *                                     **** INICBN ****
2: C---- SUBROUTINE T9 INITIALIZE MAPS
3: C---- RTR:RADTKE 3/4/74
4: SUBROUTINE INICBN
5: COMMON /ACCESS/ ACLDAD(10),PIDLMIN,PIDLMAX
6: COMMON /AIR/ AVIB,AVIR,AVIB,AVIS,AVIM
7: COMMON /BGEAR/ BGRTI9
8: COMMON /CROSSCR/ VMIN(2),PMAX(2),VINT(2),NDIM(2)
9: COMMON /COMMENT/ CBMM(26)
10: COMMON /CONTROL/ GAIN,DELMIN,NVEPA,IVEPA(685)
11: COMMON /DSSPD/ T8INV(10)
12: COMMON /ENGIN/SCALEF,TIDLE,EVS,TS
13: COMMON /GAS/ FUELWT
14: COMMON /GEAREF/ TBC1GI(10,4),IBC1GI(10)
15: COMMON /INERTIA/ FIE,RIEINV
16: COMMON /LOCKER/ TIMLOCK,SRNEW,TRNEW,TROLD,SROLD
17: COMMON /LOCK1/ ACCLOCK,DECLCK
18: COMMON /LOCK2/ ACCRUIS
19: COMMON /MASS/ VVILF,VV1ICB,VV1IRF,VVIMI,VV12BR,VVIM,VVIMDR,
20: C VVISWB,VVISH,VVIAMX,VVIAS
21: COMMON /PMMENT/ TVIJCT,TVIJIR,TVIJRA,TVIJTW
22: COMMON /PRNT/ IBUT,IPRNT,LOADEQ,MAXLIN
23: COMMON /ROLD/ TVICRL(16)
24: COMMON /RGRTI9/ T811GR
25: COMMON /SFTIME/ T8DTMS,T8DTH
26: COMMON /SHIFTER/ GRMAX(3),GRMIN(3),GRMAXCR(3)
27: COMMON /STEADY/ EPS
28: COMMON /TGRTI9/ T5C1GR(10),GR1
29: COMMON /TIRE/ VVIDRR,VVIFUM,VVIFUS,VV11CF
30: COMMON /TIME1/ DT
31: COMMON /TQC/ AAY(20,3)
32: *
33: 100 FORMAT(11I7/6I7)
34: 101 FORMAT(20I4)
35: 102 FORMAT(16I5)
36: 103 FORMAT(10I5)
37: 104 FORMAT(8E10.3)
38: 105 FORMAT(8I10)
39: 106 FORMAT(16F5.1)
40: 107 FORMAT(5E11.5)
41: 108 FORMAT(10I1)
42: 109 FORMAT(12F6.1)
43: 110 FORMAT(13A6/13A6)
44: 111 FORMAT(13I6)
45: 112 FORMAT(F10.6)
46: 200 FORMAT(Y,11I7/6I7)
47: 201 FORMAT(X,20I4)
48: 202 FORMAT(Y,16I5)
49: 203 FORMAT(X,10I5)
50: 204 FORMAT(X,8E10.3)
51: 205 FORMAT(X,8I10)
52: 206 FORMAT(X,16F5.1)
53: 207 FORMAT(X,5E11.5)

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54: 203 FORMAT(X,10I1)
55: 209 FORMAT(12F6.1)
56: 210 FORMAT(X,13A6/13A6)
57: 211 FORMAT(13I6)
58: 212 FORMAT(F10.6)
59: *
60: 120 FORMAT (8F10.3)
61: 130 FORMAT (1H1)
62: PRINT 130
63: READ 110,CBMM
64: PRINT 110,CBMM
65: READ 120,VVIM1,VVIM2R,VVIM,VVIMDR
66: PRINT 120,VVIM1,VVIM2R,VVIM,VVIMDR
67: C---- ENGINE INERTIA, MAX TORQUE, MAX VAC, ENGINE SCALE FACTOR, IDLE SETT
68: READ 104,RIE,TMAX,SCALEF,TIDLE,PIDLMIN,PIDLMAX
69: PRINT 204,RIE,TMAX,SCALEF,TIDLE,PIDLMIN,PIDLMAX
70: C---- ACCESSORY LOAD
71: READ 104,ACLOAD
72: OUTPUT(108) 'ACLOAD'
73: PRINT 204,ACLOAD
74: C---- READ IN DEFINITION OF CROSS CORRELATION
75: READ 104,VMIN(1),PMAX(1),VINT(1)
76: READ 104,VMIN(2),PMAX(2),VINT(2)
77: OUTPUT(108) 'VMIN(1), ETC'
78: PRINT 204,VMIN(1),PMAX(1),VINT(1)
79: OUTPUT(108) 'VMIN(2), ETC'
80: PRINT 204,VMIN(2),PMAX(2),VINT(2)
81: ADIM(1)=(PMAX(1)-VMIN(1))/VINT(1)+1
82: ADIM(2)=(PMAX(2)-VMIN(2))/VINT(2)+1
83: C---- GEAR INDEX AS A FUNCTION OF DRIVE SHAFT SPEED AND ENGINE VACUUM
84: DO 50 N=1,10
85: TBC1GR(N)=0.
86: 50 CONTINUE
87: READ 103,NGEAR
88: OUTPUT(108) 'NGEAR'
89: PRINT 203,NGEAR
90: NSM1=NGEAR*2-3
91: C---- POLYNOMIAL INDEX FOR CALCULATING GEAR EFFICIENCY
92: OUTPUT(108) 'TBC1GI(I,J)'
93: DO 30 J=1,4
94: READ 107,(TBC1GI(I,J),I=1,10)
95: PRINT 207,(TBC1GI(I,J),I=1,10)
96: 30 CONTINUE
97: C---- GEAR EFFICIENCY INDEX
98: READ 108,TBC1GI
99: OUTPUT(108) 'TBC1GI'
100: PRINT 208,TBC1GI
101: C---- GEAR RATIOS
102: READ 104,(TBC1GR(J),J=1,NGEAR)
103: OUTPUT(108) 'TBC1GR(J)'
104: PRINT 204,(TBC1GR(J),J=1,NGEAR)
105: READ 112,BORTIG
106: OUTPUT(108) 'BEVEL GEAR RATIO BORTIG'

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107: PRINT 112,BGRTIO
108: C-----FIRST GEAR RATIO, POLAR MOMENT OF TORQUE CONV. TURBINE, POLAR
109: C-----MOMENT OF TRANS. GEARS, LENGTH OF SHIFT, TIME BETWEEN SHIFTS
110: READ 104, GR1,TVIJCT,TVIJTR,TBDTMS,TBDTH
111: OUTPUT(108) 'GR1, ETC'
112: PRINT 204,GR1,TVIJCT,TVIJTR,TBDTMS,TBDTH
113: C-----REAR AXLE RATIO, POLAR MOMENT OF REAR AXLE GEARS
114: READ 104, T811GR,TVIJRA
115: OUTPUT(108) 'T811GR, ETC'
116: PRINT 204,T811GR,TVIJRA
117: C-----TIRE ROLLING RADIUS,COEFF. OF MAX TIRE FRICTION, SLIDING COEFF. OF
118: C-----TIRE FRICTION, TIRE COULOMBIC FRICTION COEFF., POLAR MOMENT OF
119: C-----TIRES AND WHEELS
120: READ 104, VVIDRR,VVIFUM,VVIFUS,VVI1CF,TVIJTW
121: OUTPUT(108) 'VVIDRR, ETC'
122: PRINT 204,VVIDRR,VVIFUM,VVIFUS,VVI1CF,TVIJTW
123: C-----DRIVE SHAFT SPEED AS A FUNCTION OF VEHICLE SPEED
124: READ 109,T81NV
125: OUTPUT(108) 'T81NV'
126: PRINT 209,T81NV
127: C-----INERTIAL MASS OF VEHICLE,FRONTAL AREA,BRAKE CONSTANT,DRAG COEFF.,
128: C-----VEHICLE MASS,ROLLING FRICTION COEFF.,MASS ON DRIVE WHEELS
129: READ 104,VVILFR,VVI1CD,VVI1RF
130: OUTPUT (108) 'VVILFR,VVI1CD,VVI1RF'
131: PRINT 104, VVILFR,VVI1CD,VVI1RF
132: C-----WHEEL BASE, HEIGHT OF VEHICLE CENTER OF GRAVITY, FUEL WEIGHT
133: READ 104, VVISAB,VVISH,FUELWT
134: OUTPUT(108) 'VVISAB, ETC'
135: PRINT 204,VVISAB,VVISH,FUELWT
136: C-----AIR PRESSURE, AIR TEMP, GAIN FOR VEDYN, AUTO DRIVER MIN. LEAD TIME
137: READ 104,AVIB,AVIR,GAIN,DELMIN
138: OUTPUT(108) 'AVIB, ETC'
139: PRINT 204,AVIB,AVIR,GAIN,DELMIN
140: READ 105,ISUT,IPRNT,LEADEQ
141: OUTPUT(108) 'ISUT, ETC'
142: PRINT 205,ISUT,IPRNT,LEADEQ
143: C-----DRIVESHAFT RESISTIVE TORQUE ROAD LOAD DATA
144: READ 105,TVICRL
145: OUTPUT(108) 'TVICRL'
146: PRINT 206,TVICRL
147: C-----TIME INCREMENT
148: READ 112,DT
149: OUTPUT(108) 'DT'
150: PRINT 212,DT
151: READ 104,AVI9,AVIS
152: OUTPUT (108)AVI9,AVIS
153: 113 FORMAT (4F10.5,F10.7)
154: READ 113,(GRMAX(I),I=1,3)
155: OUTPUT (108)'GRMAX '
156: PRINT 113,(GRMAX(I),I=1,3)
157: OUTPUT (108) 'GRMAXCR CRUISE)'
158: READ 113,(GRMAXCR(I),I=1,3)
159: PRINT 113,(GRMAXCR(I),I=1,3)

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150:      OUTPUT (108) 'GRMIN 1-3'
161:      READ 113, (GRMIN(I),I=1,3)
162:      PRINT 113,(GRMIN(I),I=1,3)
163:      999 CONTINUE
164:      OUTPUT (108) 'ALLISON TEST DATA'
165:      OUTPUT (108) 'SPEED RATIO*TORQUE RATIO*ONE/X**2'
166:      DO 20,I=1,20
167:      500 FORMAT (2F10.5,F10.8)
168:      READ 500, (AWAY(I,J),J=1,3)
169:      PRINT 500,(AWAY(I,J),J=1,3)
170:      20 CONTINUE
171:      400 FORMAT (8F10.5)
172:      READ 400, SRNEW,TRNEW,SROLD,TROLD,TIMLOCK
173:      PRINT 400, SRNEW,TRNEW,SROLD,TROLD,TIMLOCK
174:      READ 400, ACCLOCK,DECLOCK
175:      PRINT 400, ACCLOCK,DECLOCK
176:      READ 400,ACCRUIS
177:      OUTPUT (108) ACCRUIS
178:      VVIARY=VVIFUP*VVI*CR*VVISWB/(VVIF*(VVISB-VVIFUP*VVISH))
179:      VVIAS=VVIFUS*VVI*MDR*VVISWB/(VVIH*(VVISB-VVIFUS*VVISH))
180:      C---- INVERSE ENGINE INERTIA
181:      RIEINV=60*32.1739/(2.*3.14159*RIE)
182:      C---- HOURS PER SECOND
183:      C---- CALCULATE AIR DENSITY
184:      AVIM=2.702912*AVIB/(459.67+AVIR)
185:      C---- LINES PER PAGE
186:      MAXLIN=48
187:      C---- ENGINE STABILITY COMPARATOR
188:      EPS=10.0
189:      TMAX=TMAX*SCALEF
190:      RETURN
191:      END

```

3.3.8 Initialization after Engine Reaches Steady State - INIGER

SUBROUTINE NAME: INIGER

TYPE OF SUBROUTINE: Initialization

DESCRIPTION: This subroutine initializes all dynamic variables which are not initialized in INIVAR. The subroutine is called after the engine has reached a steady state speed before the driving cycle begins. This subroutine then puts the bus into first gear.

MODELING: N/A

EQUATIONS: N/A

INPUT VARIABLES: S/L

OUTPUT VARIABLES: S/L

OTHER VARIABLES: N/A

PROGRAM VARIABLES: N/A

FLOW CHART: N/A

```

1:      **** INIGER ****
2:      SUBROUTINE INIGER(PAON,SBTORQ,PACFR,INDIC,ICLOCK,TIME
3:      C ,ICLOCK1,TB01EF,T9IN,T8DN,T90N,T9I1GR,VV0S,VV9A,VV0D
4:      C ,FUELE,EMISF,EMISE,ITICYC,ISHIFT,IGEAR,WHL0LD,
5:      C VV07I,DELTAI,T9IC,T9I1,LOCK,
6:      C NLINE,ICYCLE,NGI0LD,NGI,TB01GR,TB01GI,PACFRO,VV9AO
7:      C ,VV0SO,ISEQ,IPDX,TIMMAX,TIMAVG,TIMLEN,NLT,NGT,VFPA,
8:      C BS,T90C,VV0F,VV0FBR,TVIMJ,TA0C,
9:      C ICLOCK)
10: C**** THIS SUBROUTINE INITIALIZES VARIABLE TO START THE CYCLE
11:      DIMENSION NLT(2),NGT(2)
12:      DIMENSION IPDX(20,20)
13:      DIMENSION TIMMAX(5),TIMLEN(5),TIMAVG(5)
14:      COMMON /TGTIB/ TB01GR(10),GR1
15:      COMMON /RGRTIB/ T8I1GR
16:      COMMON /MAPS/ MAP1,MAP3
17:      DIMENSION MAP1(55,17),MAP3(17,17)
18:      COMMON /SETIME/ T0DTMS,T0DTH
19:      COMMON /PRNT/ IOUT,IPRNT,LOADEDQ,MAXLIN
20:      LOCK=0
21:      INDIC=0
22:      ICLOCK=0
23:      TIME=0
24:      ICLOCK=-(IOUT+1)
25:      ICLOCK1=0
26:      TB01EF=.93
27:      T9IN=0
28:      T8DN=0
29:      T90N=0
30:      T9I1GR=T8I1GR
31:      VV0S=0
32:      VV9A=0
33:      VV0D=0
34:      FUELE=0
35:      EMISF=0
36:      EMISE=0
37:      ITICYC=0
38:      ISHIFT=-T0DTH-1
39:      IGEAR=0
40:      WHL0LD=0
41:      NLINE=MAXLIN+5
42:      ICYCLE=0
43:      NGI0LD=1
44:      NGI=1
45:      TB01GR=GR1
46:      TB01GI=1
47:      PACFRO=0
48:      VV9AO=0
49:      VV0SO=0
50:      ISEQ=0
51:      DO 10 I=1,20
52:      DO 5 J=1,20
53:      IPDX(I,J)=0

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54:      5 CONTINUE
55:      10 CONTINUE
56:      DO 15 I=1,5
57:          TIMMAX(I)=0
58:          TIMAVG(I)=0
59:          TIMLEN(I)=0
60:      15 CONTINUE
61:          NLT(1)=0
62:          NLT(2)=0
63:          NGT(1)=0
64:          NGT(2)=0
65:          CALL RIX0N22(PARN,SST0RQ,PA0FR,MAP3)
66:          CALL TREFF(TASC,TB01GR,TB01EF,TB01GI,T9IN,T9IC)
67:          CALL RAEFF(T9IC,T9IN,T9I1GR,T90C,T9I1)
68:          CALL VEDYN(TB01GI,VV0S,BS,T90C,TB01GR,T9I1GR,VV0A
69:          C ,VV0F,T9I1,VVDFBR,VVDMI,DELTAT,VV0AO,
70:          C TVINJ)
71:          PA0FR0=PA0FR
72:          VV0A=0.
73:          VV0AO=VV0A
74:          VEPA=0
75:          RETURN
76:          END
```

3.3.9 Initialize Engine Variables - INIVAR

SUBROUTINE NAME: INIVAR

TYPE OF SUBROUTINE: Initialization

DESCRIPTION: This subroutine initializes those variables necessary for the engine calculations. When the engine reaches a steady state speed with the vehicle at rest, INIGER initializes all other variables.

MODELING: N/A

EQUATIONS: Initial Engine Acceleration:

$$\Delta N_E = (T_{SS} - T_A - T_E)/J_E$$

INPUT VARIABLES: S/L

OUTPUT VARIABLES: S/L

OTHER VARIABLES: N/A

PROGRAM VARIABLES: N/A

FLOW CHART: S/L

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1: *          **** INIVAR ****
2: SUBROUTINE INIVAR (BFORCE, LOCK, UDNSFT, TIME, ICLOCK, ICLOCKI
3: C , ISHIFT, NREC, BS, TB91GR, TB91GI, NGI, NGIOLD, ICYEND, VV9A, VANALG,
4: C HPXPLM, HPRAXM, HPTRANM, HPTQCM, HPENGM, HPWHLP, HPRAXP, HPTRANP,
5: C HPTQCP, HPENGP, HPACC,
6: C ACTORG, PAOC, BFORCEM, PIDLE,
7: C TAB1TR, TAB1SR, BA9C,
8: C TIMMAX, TIMLEN, TIMAVG, PABN, BA9N, SSTORG, TA9N, ESD9TO, VAR)
9: C***** INITIALIZES VARIABLES AT START OF RUN
10: DIMENSION TIMMAX(5), TIMLEN(5), TIMAVG(5), VAR(2)
11: COMMON /ENGINE/SCALEF, TIDLE, EVS, TS
12: COMMON /INERTIA/ RIE, RIEINV
13: COMMON /MAPS/ MAP1, MAP3
14: DIMENSION MAP1(55,17), MAP3(17,17)
15: COMMON /GGEAR/ G9RTIO
16: HPWHLP=HPRAXM=HPTRANM=HPTQCM=HPENGM=HPWHLP=HPRAXP=HPTRANP=
17: C HPTQCP=HPENGP=HPACC=0.0
18: BFORCE=BFORCEM=0.
19: LOCK=0
20: UDNSFT=0
21: TIME=0
22: ICLOCK=0
23: ICLOCKI=0
24: ISHIFT=0
25: TS = 100*TIDLE
26: NREC=0
27: BS=0
28: TB91GR=0
29: TB91GI=0
30: NGI=0
31: NGIOLD=0
32: ICYEND=0
33: VV9A=0.
34: VANALG=0
35: DO 5 I=1,5
36: TIMMAX(I)=0
37: TIMAVG(I)=0
38: 5 CONTINUE
39: PABN=900.
40: BA9N=PABN/G9RTIO
41: CALL RIXUN2(PABN, TS, SSTORG, MAP1)
42: SSTORG=SSTORG*SCALEF
43: TABN=0
44: CALL TQCONV( LOCK, PAOC, SSTORG, ACTORG, TAB1TR,
45: C TAB1SR, TABN, BA9N, BA9C, TABC)
46: CALL ACCESS (PABN, ACTORG)
47: ESD9TO=(SSTORG-ACTORG-PAOC)*RIEINV
48: VAR(2)=50.
49: RETURN
50: END

```

3.3.10 Integrate System Variables - INTGRT

SUBROUTINE NAME: INTGRT

TYPE OF SUBROUTINE: System Computation

DESCRIPTION: This subroutine integrates vehicle acceleration, vehicle speed and fuel rate to get vehicle velocity, distance traveled and fuel expended respectively.

MODELING: A second order integration scheme is used.

EQUATION: (Typical) $V = V_0 + (A_0 + A) \cdot (\Delta T)/2$

INPUT VARIABLES: ICLOCK - Value of System clock

ICLOCK1 - Last value of system clock

VVOS - Last vehicle speed

VVOD - Last distance traveled

FUELE - Fuel expended

VVOA - New vehicle acceleration

PAOFR - New fuel rate

VVOA0 - Old vehicle acceleration

PAOFR0 - Old fuel rate

OUTPUT VARIABLES: VVOS - New velocity

VVOD - New distance

FUELE - New fuel consumed

VVOA0 - Old acceleration for next iteration

VVOS0 - Old speed for next iteration

PAOFR0 - Old fuel rate for next iteration

ICLOCK1 - Current value of system clock

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1: *                                     **** INTGRT ****
2: SUBROUTINE INTGRT(ICLOCK,ICLK1,NTIMEP,VVOS,
3: C VVBA,VVBAO,VVBSO,PABFR,VVBD,FUELE,PABFRO)
4: C***** THIS SUBROUTINE INTEGRATES THE PROGRAM VARIABLES
5: COMMON/TIMEI/ DT
6: NTIMEP=ICLOCK
7: DELTA=(NTIMEP-ICLK1)*DT*.5
8: C***** SPEED
9: VVBS=VVBS+(VVBAO+VVBA)*DELTA
10: *
11: C***** THIS IS TO ASSURE US THAT THE BUS WILL STOP AT VERY LOW SPE
12: IF (VVBA .LE. 0 .AND. VVBS .LT. .1)VVBS=VVBA=0.0
13: *
14: C***** DISTANCE
15: VVBD=VVBD+(VVBSO+VVBS)*DELTA/3600.
16: C***** FUEL
17: FUELE=FUELE+(PABFRO+PABFR)*DELTA/3600.
18: VVBAO=VVBA
19: VVBSO=VVBS
20: PABFRO=PABFR
21: ICLK1=NTIMEP
22: RETURN
23: END

```

3.3.11 Terminate Subroutine - JPBSUM

SUBROUTINE NAME: JPBSUM

TYPE OF SUBROUTINE: Output

DESCRIPTION: This subroutine prints out a summary of the run, including the joint probability distribution, the gas mileage, total distance traveled, and power used.

MODELING: N/A

EQUATIONS: N/A

INPUT VARIABLES: S/L

OUTPUT VARIABLES: S/L

OTHER VARIABLES: N/A

PROGRAM VARIABLES: N/A

FLOW CHART: S/L

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1: *                               **** JPBSUM ****
2:      SUBROUTINE JBPSUM(IPDX, ICYCLE, NLT, NGT, VV9D, FUELF, HPWHLP,
3:      C HPXHLN, HPRAXP, HPRAXM, HPTRANP, HPTRANM, HPTGCP,
4:      C HPTGCM, HPENGP, HPENGM, HPACC, TIME,
5:      C XTIME, XSSTPR, XPA9C, XACTOR, XT9IC, XT99C, GEAR
6:      C X9BHP, ACCHP, FLYHP, CONHP, DRSHHP, RAXHP)
7: C**** THIS SUBROUTINE OUTPUTS TO THE LINE PRINTER THE PROBABILITY
8: C**** DENSITY INFORMATION, THE MILEAGE INFORMATION AND THE TORQUE TA
9: C**** OF THE FIRST 140 SECONDS
10:      DIMENSION SUMJ(20), X(225), NGT(2), NLT(2)
11:      DIMENSION IPDX(20,20)
12:      DIMENSION XTIME(140), XSSTPR(140), YPA9C(140), XACTAR(140)
13:      DIMENSION XT9IC(140), XT99C(140), GEAR(140)
14:      DIMENSION X9BHP(140), ACCHP(140), FLYHP(140), CONHP(140)
15:      DIMENSION DRSHHP(140), RAXHP(140)
16:      COMMON /SPD/ ISPEED(20)
17:      COMMON /CRESCR/ VMIN(2), VMAX(2), VINT(2), NDIM(2)
18:      COMMON /GAS/ FUELWT
19:      COMMON /STOPPER/ NSTOP
20: C---- TERMINATION SUBROUTINE
21: C**** RICK HUDSON 1/77
22: C---- R.R. RADTKE 3/5/74
23:      200 FORMAT(1H1,          40X, 36HJBINT PROBABILITY DENSITY (PER CENT
24:      199 FORMAT (/, (20X, 13A6))
25:      201 FORMAT(//, 39X, 43HENGINE STEADY STATE TORQUE VS. ENGINE SPEED)
26:      202 FORMAT( /, 52X, 15HSPEED INTERVALS )
27:      203 FORMAT(1H )
28:      204 FORMAT(2X, 20F6.2)
29:      205 FORMAT(1X, 6HTORQUE, //, 1X, 9HINTERVALS)
30:      206 FORMAT(1X, 13, 1H-, 13, 20F6.2)
31:      207 FORMAT(//, 5X, 15, 36H SAMPLES FELL BELOW THE MINIMUM TORQUE,
32:      1 //, 5X, 15, 36H SAMPLES EXCEEDED THE MAXIMUM TORQUE,
33:      2 //, 5X, 15, 37H SAMPLES FELL BELOW THE MINIMUM SPEED,
34:      3 //, 5X, 15, 35H SAMPLES EXCEEDED THE MAXIMUM SPEED)
35:      208 FORMAT(1H1, 5X, 17, 37H ITERATIONS TOOK PLACE OVER THE CYCLE)
36:      209 FORMAT(2H TOTALS, 20F6.2)
37:      212 FORMAT(12X, 46HONE SAMPLE TAKEN DURING EACH PROGRAM ITERATION)
38:      PRINT 200
39:      PRINT 201
40:      PRINT 202
41:      PRINT 203
42:      ISPEED(1)=VMIN(2)
43:      INT=VINT(2)
44:      NLIM=NDIM(2)
45:      DO 5 I=2, NLIM
46:      ISPEED(I)=ISPEED(I-1)+INT
47:      5 CONTINUE
48:      N2=NDIM(2)-1
49:      PRINT 204, (ISPEED(I), I=1, N2)
50:      PRINT 204, (ISPEED(I), I=2, NLIM)
51:      PRINT 203
52:      ITERG1=VMIN(1)
53:      INT=VINT(1)

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IS SIMULATION PROGRAM

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54:      N1=NDIP(1)-1
55:      D9 10 I=1,NLIM
56:      10 SUMJ(I)=0
57:      D9 20 I=1,N1
58:      ITERG1=ITERG1+INT
59:      D9 15 J=1,N2
60:      X(J)=FLGAT(IPDX(I,J))*100./FLGAT(ICYCLE)
61:      SUMJ(J)=SUMJ(J)+X(J)
62:      15 CONTINUE
63:      PRINT 206,ITERG1,ITERG2,(X(J),J=1,N2)
64:      ITERG1=ITERG2
65:      20 CONTINUE
66:      PRINT 205
67:      PRINT 203
68:      PRINT 209,(SUMJ(J),J=1,N2)
69:      PRINT 203
70:      PRINT 208,ICYCLE
71:      PRINT 212
72:      PRINT 207,(NLT(I),NST(I),I=1,2)
73:      210 FORMAT(///,10X,17HMILES PER GALLON=,F7.3)
74:      FUMPG=VVOO*FUEL*17/FUELE
75:      PRINT 210,FUMPG
76:      505 FORMAT(10X,17 GALLONS PER MILE=,F7.3)
77:      FUGPM=1/FUMPG
78:      PRINT 505,FUGPM
79:      507 FORMAT (40HPPOWER REQUIRED BY THE REAR AXLE ,F8.2,10X,F8.2)
80:      506 FORMAT (///,40HPPOWER REQUIRED BY THE WHEEL
81:      C ,F8.2,10X,F8.2 )
82:      508 FORMAT (40HPPOWER REQUIRED BY THE DRIVE SHAFT ,F8.2,10X,F8.2)
83:      509 FORMAT (40HPPOWER REQUIRED BY THE TORQUE CONVERTER , F8.2,10X,
84:      C ,F8.2)
85:      510 FORMAT (40HPPOWER REQUIRED BY THE ENGINE FLYWHEEL ,F8.2,10X,F8.2)
86:      511 FORMAT (40HPPOWER REQUIRED BY THE ACCESSORIES ,F8.2,10X,F8.2)
87:      512 FORMAT(40X , 27HDRIVE*****MOTORING )
88:      513 FORMAT (10X,///, 25HNUMBER OF STOPS PER MILE=
89:      C ,12)
90:      514 FORMAT (///,40X,2CHORSEPOWER-SECONDS )
91:      515 FORMAT (40HPPOWER LOST TO BRAKES
92:      C ,18X,F8.2)
93:      PRINT 513,NSTOP
94:      PRINT 211,VVOO
95:      PRINT 514
96:      PRINT 512
97:      PRINT 506,HPAHL,HPWHL
98:      PRINT 507,HPRAXP,HPRAXY
99:      PRINT 508,HPTRANP,HPTRANM
100:      PRINT 509,HPICCP,HPICCM
101:      PRINT 510,HPENGP,HPENGM
102:      PRINT 511,HPACC
103:      211 FORMAT(10X,9HDISTANCE=,F7.4)
104:      PRINT 213
105:      213 FORMAT(1H1,20X,28HTORQUE VALUES IN DRIVE TRAIN)
106:      PRINT 214

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BUS SIMULATION PROGRAM

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107: 214 FORMAT(///,22X,6HENGINE,16X,12HTRANSMISSION,5X,9HREAR AXLE)
108: PRINT 230
109: 230 FORMAT(/,33X,7HDYNAMIC,3X,7HDYNAMIC,2X,7HDYNAMIC,3X,7HDYNAMIC)
110: PRINT 215
111: 215 FORMAT(5X,4HTIME,3X,2HINSTANT.,4X,4HACC.,4X,8HFLYWHEEL,2X,
112: 19HCONVERTER,2X,6HDRIVE-,3X,9HREAR AXLE,6X,4HGEAR)
113: PRINT 216
114: 216 FORMAT(13X,6HENGINE,4X,6HTORQUE,4X,6HTORQUE,4X,6HOUTPUT,
115: 14X,5HSHAFT,5X,6HOUTPUT)
116: PRINT 217
117: 217 FORMAT(13X,6HTORQUE,24X,6HTORQUE,4X,6HTORQUE,4X,6HTORQUE)
118: ITEMP=TIME
119: IF (TIME .GT. 140) ITEMP=140
120: DO 500, I=1, ITEMP
121: PRINT 218,XTIME(I),XSSTOR(I),XACTOR(I),XPAOC(I),XTAOC(I),
122: 1XT9IC(I),XT98C(I),GEAR(I)
123: 500 CONTINUE
124: 218 FORMAT(7F10.2,F9.0)
125: PRINT 219
126: 219 FORMAT(1H1,18X,32HHORSEPOWER VALUES IN DRIVE TRAIN)
127: PRINT 214
128: PRINT 230
129: PRINT 215
130: PRINT 220
131: 220 FORMAT(13X,6HENGINE,6X,2HHP,8X,2HHP,6X,6HOUTPUT,4X,
132: 15HSHAFT,5X,6HOUTPUT)
133: PRINT 221
134: DO 501 I=1, ITEMP
135: 221 FORMAT(15X,2HHP,6X,4HLOSS,18X,2HHP,8X,2HHP,8X,2HHP)
136: PRINT 218,XTIME(I),X95HP(I),ACCHP(I),FLYHP(I),CHNHP(I),DRSHP(I)
137: 1RAXHP(I),GEAR(I)
138: 501 CONTINUE
139: RETURN
140: END

```

3.3.12 Converter Lockup - LOCKUP and LOCKCAL

SUBROUTINE NAMES: LOCKUP and LOCKCAL

TYPE OF SUBROUTINE: System Computation

DESCRIPTION: These subroutines simulate the effect of the torque converter lockup process by calculating the torque ratio and speed ratio of the torque converter.

MODELING: This routine is activated if the vehicle velocity has exceeded a maximum acceleration velocity or a maximum cruising velocity. It is activated during each iteration thereafter until the vehicle velocity drops below a minimum for the lockup. When the subroutine is first activated it calculates the converter's speed ratio and torque ratio and changes them linearly between the old ratios and the lockup ratios over 1-1/2 second period. When it unlocks it follows the same process.

INPUT VARIABLES:

VVOS Vehicle Velocity

TIME

INPUT AND OUTPUT VARIABLES:

LOCK	Indicates whether torque converter is locking, locked, or unlocking
TIME	Time of run
TAILSR	Torque converter speed ratio
TAOLTR	Torque converter Torque ratio

CONSTANTS IN MEMORY:

ACCLOCK	Speed at which lockup occurs if accelerating
DELOCK	Speed at which you unlock
ACCRUS	Speed at which lockup occurs if cruising

CONSTANTS IN MEMORY (CONTINUED)

TIMLOCK	Length of time taken to lockup
---------	--------------------------------

PROGRAM VARIABLES:

SRNEW	Speed ratio when locked up
TRNEW	Torque ratio when locked up
SROLD	Speed ratio after unlocking
TROLD	Torque ratio after unlocking
DELSR	Δ speed ratio
DELTR	Δ torque ratio
DONLOCK	Time lockup is complete

TC490 LOCKUP SCHEDULE

WOT LOCKUP	28 MPH
CR LOCK	21 MPH
UNLOCK	9 MPH

BUS SIMULATION PROGRAM

DA:

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1: *                      **** LOCKUP ****
2:      SUBROUTINE LOCKUP(VVGS,TIME,LOCK,TAI1SR,TAG1TR)
3: C***** THIS SUBROUTINE SIMULATES THE CONVERTER LOCKING US
4: C***** LOCK IS USED AS A FLAG TO SEE IF WE ARE LOCKING(2) UNLOCKING (3)
5: C***** ARE ALREADY LOCKED (1)
6: *
7:      COMMON /LOCK1/ ACCLOCK,DECLOCK
8:      COMMON /LOCKER/ TIMLOCK,SRNEW,TRNEW,TROLD,SROLD
9: *
10:     GO TO (2,100,200,300) LOCK+1
11:     2 CONTINUE
12: C***** LOCKUP
13:     LOCK = 2
14:     CALL LOCKCAL(LOCK,TAI1SR,TAG1TR,TIME,DONLOCK,DELSR,DELTR)
15:     TAG1TR=TAG1TR+DELTR
16:     TAI1SR=TAI1SR+DELSR
17:     GOTO 999
18: *
19:     100 CONTINUE
20: C***** LOCKED UP
21:     IF (VVGS .LT. DECLOCK) GOTO 110
22:     TAI1SR= SRNEW
23:     TAG1TR=TRNEW
24:     GOTO 999
25:     110 CONTINUE
26: C***** UNLOCK
27:     LOCK=3
28:     CALL LOCKCAL(LOCK,TAI1SR,TAG1TR,TIME,DONLOCK,DELSR,DELTR)
29:     TAI1SR=TAI1SR+DELSR
30:     TAG1TR=TAG1TR+DELTR
31:     GOTO 999
32: *
33:     200 CONTINUE
34: C***** LOCKING UP
35:     IF (DONLOCK .LT. TIME) GOTO 210
36:     TAG1TR=TAG1TR+DELTR
37:     TAI1SR=TAI1SR+DELSR
38:     GOTO 999
39:     210 CONTINUE
40: C***** LOCKIED UP
41:     LOCK=1
42:     TAI1SR= SRNEW
43:     TAG1TR=TRNEW
44:     GOTO 999
45: *
46:     300 CONTINUE
47: C***** UNLOCKING
48:     IF ( DONLOCK .LT. TIME) GOTO 310
49:     TAG1TR=TAG1TR+DELTR
50:     TAI1SR=TAI1SR+DELSR
51:     GOTO 999
52:     310 CONTINUE
53: C***** UNLOCKED
```

RUS SIMULATION PROGRAM

54: LOCK=0

55: 999 CONTINUE

56: RETURN

57: END

BUS SIMULATION PROGRAM

```
1: * **** LOCKCAL ****
2: SUBROUTINE LOCKCAL (LOCK, SR, TR, TIME, DSNLOCK, DELSR, DELTR)
3: C***** THIS SUBROUTINE CALCULATES THE CHANGES IN THE CONVERTER CONDIT
4: C***** LOCKUP
5: COMMON /LOCKER/ TIMLOCK, SRNEW, TRNEW, TROLD, SROLD
6: COMMON /TIME1/ DT
7: * 28 DEC 1976
8: *
9: DTT = DT * TIMLOCK
10: GO TO (200, 300) LOCK-1
11: *
12: 200 CONTINUE
13: C***** LOCKING UP
14: DELSR = (SRNEW - SR) * DTT
15: DELTR = (TRNEW - TR) * DTT
16: GO TO 999
17: *
18: 300 CONTINUE
19: C***** UNLOCKING
20: DELTR = (TROLD - TR) * DTT
21: DELSR = (SROLD - SR) * DTT
22: *
23: 999 CONTINUE
24: DSNLOCK = TIME + TIMLOCK
25: RETURN
26: END
```

3.3.13 Subroutine to Input Engine Map - MAPER

SUBROUTINE NAME: MAPER

TYPE OF SUBROUTINE: Input

DESCRIPTION: This subroutine reads in the engine maps used to calculate fuel consumption and minimum engine torque.

MODELING: The program reads in the engine speed on the first card. The second card reads in nine torques. The third card reads in the corresponding fuel rate and the fourth card reads in corresponding throttle setting. The fifth card is blank. This is repeated for eight different engine speeds. Next the first line of the arrays to be used by RIXON2. MAPER then creates MAP1 which is engine torque as a function of throttle setting and engine speed. MAP3 which is fuel consumption as a function of engine speed and engine torque. See RIXON2 for a complete description of the make up and use of the arrays.

CONSTANTS STORED

MEANING

MAP1	Engine torque as a function of engine speed and throttle setting
MAP3	Fuel consumption as a function of engine speed and torque.

BUS SIMULATION PROGRAM

```

1: *                                     **** MAPER ****
2:      SUBROUTINE MAPER
3: C***** THIS SUBROUTINE READS IN THE ENGINE MAPS
4:      COMMON /MAPS/ MAP1,MAP3
5:      DIMENSION MAP1(55,17),MAP3(17,17)
6:      DIMENSION F(50,9)
7:      900 FORMAT(5X,9F7.2)
8: *
9: C----READ NEW MAPS
10:      910 FORMAT (9I7)
11:      DO 10 I=1,40,1
12:      READ 900,(F(I,J),J=1,9)
13:      PRINT 900,(F(I,J),J=1,9)
14:      10 CONTINUE
15:      DO 11 I=1,17
16:      DO 14 J=1,17
17:      MAP1(I,J)=0
18:      14 CONTINUE
19:      11 CONTINUE
20:      READ 910 , (MAP1(1,K),K=1,8) , MAP1(2,1)
21:      OUTPUT (108) 'FIRST LINE IN ARRAY'
22:      PRINT 910 , (MAP1(1,K),K=1,8) , MAP1(2,1)
23:      DO 20 I=3,53,1
24:      MAP1(I,1)=(I-3)*2
25:      20 CONTINUE
26:      DO 30 I=2,11,1
27:      MAP1(2,I)=I*200+400
28:      30 CONTINUE
29:      DO 40 I=2,11,1
30:      NN=2+(I-2)*5
31:      J=2
32:      IT=(F(NN,J-1)*F(NN+2,J)-F(NN,J)*F(NN+2,J-1))/
33:      1(F(NN+2,J)-F(NN+2,J-1))
34:      MAP1(3,1)=IT*100
35:      40 CONTINUE
36:      K=3
37:      DO 100 N=2,100,2
38:      K=K+1
39:      L=1
40:      DO 90 I=4,39,5
41:      L=L+1
42:      DO 50 J=2,9,1
43:      TS=F(I,J)/0.8093
44:      61 IF (TS-N)610,60,70
45:      610 IF (N.EQ. 100 .AND. J.EQ. 9) GOTO 70
46:      GOTO 50
47:      60 TBR=F(I-2,J)*100
48:      MAP1(K,L)=TBR
49:      GO TO 90
50:      70 TBR=100*(F(I-2,J-1)+(F(I-2,J)-F(I-2,J-1))*((N*RC.930/100-
51:      1F(I,J-1))/(F(I,J)-F(I,J-1))))
52:      MAP1(K,L)=TBR
53:      GO TO 90

```

BUS SIMULATION PROGRAM

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54:      50 CONTINUE
55:      90 CONTINUE
56:      100 CONTINUE
57:      READ 910 , (MAP3(1,K),K=1,8) , MAP3(2,1)
58:      PRINT 910 , (MAP3(1,K),K=1,8),MAP3(2,1)
59:      I=3
60:      DO 210 IT=-50,950,100
61:      MAP3(1,1)=IT
62:      I=I+1
63:      210 CONTINUE
64:      DO 310 I=2,11,1
65:      MAP3(2,I)=I*200+400
66:      310 CONTINUE
67:      K=1
68:      DO 54 N=0,9,1
69:      K=K+1
70:      M=1
71:      J=2
72:      DO 52 I=-50,950,100
73:      J=J+1
74:      IF (I-F(2+N*5,M)) 39,49,59
75:      39 MAP3(J,K)=F(3+N*5,1)*100
76:      GO TO 52
77:      49 MAP3(J,K)=F(3+N*5,M)*100
78:      GO TO 52
79:      59 IF (I-F(2+N*5,M+1)) 65,65,66
80:      66 M=M+1
81:      IF (M=9) 59,55,55
82:      55 MAP3(J,K)=F(3+N*5,9)*100
83:      M=M+1
84:      GO TO 52
85:      65 MAP3(J,K)=(F(3+N*5,M)-((F(3+N*5,M)-F(3+N*5,M+1))*(I-F(2+N*5,M)))
86:      1/(F(2+N*5,M+1)-F(2+N*5,M))))*100
87:      52 CONTINUE
88:      54 CONTINUE
89:      PRINT 502
90:      502 FORMAT(/,18HMAP1-ENGINE TORQUE,/)
91:      DO 130 I=1,13,1
92:      ISIZEY=9
93:      PRINT 500,(MAP1(I,J),J=1,ISIZEY)
94:      130 CONTINUE
95:      C PRINT 503
96:      503 FORMAT(/,20HMAP2-MANIFOLD VACUUM,/)
97:      C DO 131 I=1,13,1
98:      C PRINT 500,(MAP2(I,J),J=1,11)
99:      C 131 CONTINUE
100:      PRINT 504
101:      504 FORMAT(/,14HMAP3-FUEL RATE,/)
102:      DO 132 I=1,13,1
103:      PRINT 500,(MAP3(I,J),J=1,ISIZEY)
104:      132 CONTINUE
105:      500 FORMAT(11I7)
106:      RETURN
107:      END

```

3.3.14 Subroutine to Output Constants - OUTCON

SUBROUTINE NAME: OUTCON

TYPE OF SUBROUTINE: Output

DESCRIPTION: This subroutine outputs constants describing the current computer run as the first record on the record of performance data file.

MODELING: N/A

EQUATIONS: N/A

INPUT VARIABLES: S/L

OUTPUT VARIABLES: S/L

OTHER VARIABLES: N/A

PROGRAM VARIABLES: N/A

FLOW CHART: S/L

BUS SIMULATION PROGRAM

1:	*	**** BUTCON ****
2:	SUBROUTINE BUTCON	
3:	C***** USED TO OUTPUT TO THE TAPE DRIVE CONSTANTS THAT ARE RELEVANT	
4:	CONTINUE	
5:	RETURN	
6:	END	

3.3.15 Subroutine to Output During Execution - OUTPUT

SUBROUTINE NAME: OUTPUT

TYPE OF SUBROUTINE: Output

DESCRIPTION: This subroutine prints out information during the execution of the all-digital program. It skips to the top of the page and prints new titles after fifty lines have been printed on one page.

EQUATIONS:

- 1) Brake specific fuel consumption

$$FC = FR/HP$$

- 2) Fuel consumption in miles/hour

$$FMPG = V * FW/TFC$$

- 3) Torque converter efficiency

$$N_{CO} * T_{CO} / (N_E * T_E)$$

INPUT VARIABLES: S/L

OUTPUT VARIABLES: None

OTHER VARIABLES: N/A

PROGRAM VARIABLES: N/A

FLOW CHART: S/L

```

1: *                **** OUTPUT ****
2:      SUBROUTINE OUTPUT (NLINE,PAQFR,ABHP,VVBS,FUELE,
3:      C VVBS,TIME,VVMA,PAQN,SSSTORQ,TAI1SR,TAB1TR,TB01EF,
4:      C T9I1,TB01GI,TAGN,TAB0C,PA0C,VV0D)
5: C***** OUTPUTS INFORMATION TO THE LINE PRINTER DURING EXECUTION
6:      COMMON /COMMENT/ COMM(26)
7:      COMMON /GAS/ FUELWT
8:      COMMON /PRNT/ IOUT,IPRNT,LOADEQ,MAXLIN
9: C---- SUBROUTINE TO OUTPUT DURING EXECUTION
10: C---- R.R.RADTKE 3/5/74
11:      90 FORMAT(1H1,20X,13A6,/,21X,13A6)
12:      102 FORMAT(/, 9X,21H-----VEHICLE-----,2X,20H-----ENGINE-----,
13:      12X,21H-----FUEL RATE-----,2X,6HACCUMU,2X,19H--TORQUE CONVERTOR--
14:      2,2X,12H-DRIVETRAIN-)
15:      103 FORMAT (3X,4HTIME,2X,21HDIST. SPEED ACCEL.,2X,19HSPEED TORQUE
16:      1POWER,3X,22H(LB/ *INSTANTANEOUS*,1X,6HLATIVE,2X,19HSPEED TORQUE
17:      2EFFIC,2X,12H TR RA GE)
18:      104 FORMAT (2X,5H(SEC),2X,22H(MI) (MPH) (MPH/SEC),1X,19H(RPM) (FT-LB
19:      1) (HP),3X,21HHP-HR) (LB/HR) (MPG),3X,5H(MPG),2X,18HRTATIO RATIO
20:      2IENCY,3X,12HEFF. EFF. AR)
21:      105 FORMAT (1X,F7.2,F5.3,F7.2,F9.3,F8.0,F7.1,F6.1,F8.3,F8.2,F8.2,F8.2
22:      1,F7.3,F7.3,F6.3,F7.3,1X,F4.3,F3.0)
23:      106 FORMAT (1X,F7.2,F5.3,F7.2,F9.3,F8.0,F7.1,F6.1,5X,3H* ,F8.2,F8.2
24:      1,F8.2,F7.3,F7.3,F6.3,F7.3,1X,F4.3,F3.0)
25: C***** BRAKE SPECIFIC FUEL CONSUMPTION
26:      BSFC=PAQFR/ABHP
27: C***** FUEL IN MILES PER GALLON
28:      FMPG=VVBS*FUELWT/PAQFR
29:      ***** TORQUE CONVERTER EFFICIENCY
30:      TCEFF=TAGN*TAB0C/(PAQN*PA0C)
31:      FMPGC=0
32:      IF(FUELE)4,4,3
33: C***** CONTINUOUS FUEL IN MILES PER GALLON
34:      3 FMPGC=VV0D*FUELWT/FUELE
35:      4 CONTINUE
36:      VVMA=VVBA
37:      NLINE=NLINE+1
38: C***** CHECK TO SEE IF AT END OF PAGE
39:      IF(NLINE-MAXLIN)20,20,5
40:      5 CONTINUE
41: C***** IF SO OUTPUT PAGE EJECT AND PRINT HEADING
42:      PRINT 90,(COMM(I),I=1,26)
43:      PRINT 102
44:      PRINT 103
45:      PRINT 104
46:      IF(NLINE-MAXLIN-4)10,10,15
47:      10 MAXLIN=47
48:      15 NLINE=1
49:      20 CONTINUE
50:      IF(BSFC)80,80,70
51:      70 CONTINUE
52:      IF(BSFC-2.)73,73,80
53:      80 CONTINUE

```

JS SIMULATION PROGRAM

54:	PRINT 106, TIME, VV0D, VV0S, VVMA, PA0N, SST0RQ, 00HP,	PA0FR, FMPG,
5	1FMPGC, TAI1SR, TA01TR, TCEFF, T001EF, T911, T001G1	
56:	G0 T0 99	
57:	73 CONTINUE	
58:	PRINT 105, TIME, VV0D, VV0S, VVMA, PA0N, SST0RQ, 00HP, BSFC, PA0FR, FMPG,	
59:	1FMPGC, TAI1SR, TA01TR, TCEFF, T001EF, T911, T001G1	
60:	99 CONTINUE	
61:	RETURN	
62:	END	

3.3.16 Tape or Disk Output Subroutine - OUTVAR

SUBROUTINE NAME: OUTVAR

TYPE OF SUBROUTINE: Output

DESCRIPTION: This subroutine outputs the current value
of the state vector on the system output file.

MODELING: N/A

EQUATIONS: N/A

INPUT VARIABLES: S/L

OUTPUT VARIABLES: S/L

OTHER VARIABLES: N/A

PROGRAM VARIABLES. N/A

FLOW CHART: S/L

BUS SIMULATION PROGRAM

1:	*	**** OUTVAR ****
2:	SUBROUTINE OUTVAR	
3:	C***** THIS SUBROUTINE OUTPUTS TO THE TAPE DRIVE VARIABLES CHOSEI	
4:	CONTINUE	
5:	RETURN	
6:	END	

3.3.17 Subroutine to Store Power Used - POWER

PROGRAM NAME: POWER

TYPE OF SUBROUTINE: Bookkeeping

DESCRIPTION: This subroutine calculates the power being
used by the bus at various points.

MODELING: S/L

VARIABLES: S/L

EQUATIONS: S/L

BUS SIMULATION PROGRAM

D

```

1: SUBROUTINE POWER(PA0C,PA0N,TA0C,TA0N,T9IN,T9IC,T90N,T90C,ACT0RQ
2: C ,SST0RQ,VV0A,BF0RCE,BF0RCEM,
3: C HPWHLM,HPRAXM,HPTRANM,HPTQCM,HPENGM
4: C ,HPWHLP,HPRAXP,HPTRANP,HPTQCP,HPENGP,HPACC)
5: COMMON/TIMEI/ DT
6: REAL K
7: K=5252.
8: ACC=ACT0RQ*PA0N*DT/K
9: ENG=SST0RQ*PA0N*DT/K
10: TQC=PA0N*PA0C*DT/K
11: TRAN=TA0C*TA0N*DT/K
12: RAX=T9IN*T9IC*DT/K
13: WHL=RAX*.92
14: IF (SST0RQ .GE. 0.) GOT0 20
15: 10 CONTINUE
16: HPWHLM=HPWHLM+WHL
17: HPRAXM=HPRAXM+RAX
18: HPTRANM=HPTRANM+TRAN
19: HPTQCM=HPTQCM+TQC
20: HPENGM=HPENGM+ENG
21: BRAKE=BF0RCE*PA0N/5252. *DT
22: BF0RCEM=BF0RCEM+BRAKE
23: GOT0 30
24: 20 CONTINUE
25: HPWHLP=HPWHLP+WHL
26: HPRAXP=HPRAXP+RAX
27: HPTRANP=HPTRANP+TRAN
28: HPTQCP=HPTQCP+TQC
29: HPENGP=HPENGP+ENG
30: 30 CONTINUE
31: HPACC=HPACC+ACC
32: RETURN
33: END

```

3.3.18 Probability Density Function - PRBDEN

SUBROUTINE NAME: PRBDEN

TYPE OF SUBROUTINE: System Computation

DESCRIPTION: This subroutine calculates the joint probability density distribution of engine speed versus steady state torque over a given driving cycle.

MODELING: This subroutine is written in generalized format so that joint probability density of any two variables can be recorded. However, it is presently used to determine the joint probability density of engine speed and torque.

The probability distribution is determined by counting the number of computational iterations the two specified variables fall within given intervals. The joint probability density is determined by JPBSUM at the end of the simulation when the number of samples within each interval is divided by the total number of samples recorded during the run. (One sample is taken during each computational iteration.)

EQUATIONS: N/A

INPUT VARIABLES: VAL(2) - Current engine speed
VAL (1) - Current steady state torque
NLT(1) - Number of samples below minimum engine speed
NLT(2) - Number of samples below minimum torque
NGT(1) - Number of samples above maximum engine speed
NGT(2) - Number of samples above maximum torque
IPDX(20,20) - New probability distribution
VMIN(1) - Minimum torque
VMIN(2) - Minimum engine speed

INPUT VARIABLES (CONTINUED)

VMAX(1) - Maximum torque

VMAX(2) - Maximum engine speed

VINT(1) - Size of torque interval

VINT(2) - Size of engine speed interval

INT1 - Torque index

INT2 - Engine speed index

S/L

STAN LS, 80

1: *

**** PRUDEN ****

C---- SUBROUTINE TO CALCULATE THE JOINT PROBABILITY DENSITY OF TWO VARIABLE

3: C---- DAN KAPPELLEN 2/74

4: SUBROUTINE PRUDEN (VAL1, VAL2, NLT, NGT, IPDX)

5: COMMON /CRSCHR/ VMIN(2), VMAX(2), VINT(2), NDIM(2)

6: DIMENSION IPDX(20,20)

7: DIMENSION NLT(2), NGT(2)

8: C*****

9: C---- THIS SUBROUTINE CALCULATES THE JOINT PROBABILITY DENSITY OF TWO

10: C---- SPECIFIED FUNCTIONS DURING THE DRIVING CYCLE. THE PROGRAM

11: C---- VARIABLES ARE AS FOLLOWS,

12: C-----INPUT VARIABLES-----

13: C---- VAL1 ----CURRENT VALUE OF FIRST SPECIFIED VARIABLE.

14: C---- VAL2 ----CURRENT VALUE OF SECOND SPECIFIED VARIABLE.

15: C-----OUTPUT VARIABLES-----

16: C---- NLT(1)---NUMBER OF SAMPLES BELOW SPECIFIED MINIMUM FOR EACH VARIABLE

17: C---- NGT(1)---NUMBER OF SAMPLES ABOVE SPECIFIED MAXIMUM FOR EACH VARIABLE

18: C---- IPDX(I,J)--INTEGER TABLE OF PROBABILITY DENSITY DISTRIBUTION.

19: C-----OTHER PROGRAM VARIABLES-----

20: C---- VMIN(1)---SPECIFIED MINIMUM FOR EACH VARIABLE.

21: C---- VMAX(1)---SPECIFIED MAXIMUM FOR EACH VARIABLE.

22: C---- VINT(1)---SPECIFIED INTERVAL LENGTH FOR EACH VARIABLE.

23: C---- INT1---TABLE INDEX FOR FIRST VARIABLE.

24: C---- INT2---TABLE INDEX FOR SECOND VARIABLE.

25: C---- THE JOINT PROBABILITY DENSITY IS DETERMINED AS A PERCENTAGE AT THE

26: C---- END OF THE CYCLE IN JPBSUM.

27: C*****

28: C---- DETERMINE IF VALUE OF VARIABLES FALL BELOW THEIR SPECIFIED MINIMUM.

29: IF (VAL1 - VMIN(1)) 131, 132, 132

30: 132 IF (VAL1 - VMAX(1)) 135, 135, 134

31: 131 NLT(1)=NLT(1)+1

32: GO TO 135

33: 134 NGT(1)=NGT(1)+1

34: GO TO 135

35: C---- DETERMINE IF THE VALUE OF THE VARIABLES FALL ABOVE THEIR SPECIFIED

36: 135 IF (VAL2 - VMIN(2)) 136, 137, 137

37: 137 IF (VAL2 - VMAX(2)) 140, 140, 138

38: 136 NLT(2)=NLT(2)+1

39: RETURN

40: 138 NGT(2)=NGT(2)+1

41: RETURN

42: C---- DETERMINE THE TABLE INDICES FOR EACH OF THE VARIABLES AS DETERMINED

43: C---- BY THE INTERVAL IN WHICH THE VALUES FALL.

44: 140 INT1=(VAL1 - VMIN(1))/VINT(1)+1.

45: INT2=(VAL2 - VMIN(2))/VINT(2)+1.

46: C---- UPDATE THE PROPER ARRAY ELEMENT IN THE TABLE.

47: IPDX(INT1, INT2)=IPDX(INT1, INT2)+1

48: RETURN

49: END

3.3.19 Subroutine to Print Constants - PRTCON

SUBROUTINE NAME: PRTCON

TYPE OF SUBROUTINE: Output

DESCRIPTION: This subroutine skips to the top of the
page and prints out the constants defining
the car being simulated.

EQUATION: N/A

INPUT VARIABLES: S/L

OUTPUT VARIABLES: S/L

PROGRAM VARIABLES: N/A

FLOW CHART: S/L

**** PRTCON ****

```

1: *
2: C-----DAN KAPPELLEN 4/30/74
3: *****
4: SUBROUTINE PRTCON
5: COMMON /AIR/ AVIE,AVIR,AVIB,AVIS,AVIM
6: COMMON /ACCESS/ ACL9AD(10),PIDLMIN,PIDLMAX
7: COMMON /BGEAR/ BGRTO
8: COMMON /COMMENT/ CBMM(26)
9: COMMON /CONTROL/ GAIN,DELMIN,NVEPA,IVEPA(685)
10: COMMON /DSSPD/ T8INV(2)
11: COMMON /ENGINE/SCALEF,TIDLE,EVS,TS
12: COMMON /EPASH/ VCRUS,ACFL,DECEL, TDWELL
13: COMMON /GAS/ FUELWT
14: COMMON /GEAREF/ TBC1GI(10,4),IBC1GI(10)
15: COMMON /INERTIA/ RIE,RTEINV
16: COMMON /LOCK1/ ACCLOCK,DECLOCK
17: COMMON /MASS/ VVILFR,VVITCD,VVITRF,VVIMI,VVITBR,VVIM,VVIMDR,
18: C VVISWB,VVISH,VVIAMX,VVIAS
19: COMMON /PROPERTY/ TVIUCT,TVIJTR,TVIJRA ,TVIJTW
20: COMMON /PRNT/ IPUT,IPRNT,LOADEQ,MAXLIN
21: COMMON /RDLD/ TVICRL(16)
22: COMMON /RGRTIO/ T8I1GR
23: COMMON /SFTIME/ T8DTMS,T8DTH
24: COMMON /STOPPER/ NSTAP
25: COMMON /SHIFTER/ GRMAX(3),GRMIN(3),GRMAXCR(3)
26: COMMON /TGRTIO/ TBC1GR(10),GR1
27: COMMON /TIRE/ VVIDRR,VVIFUM,VVIFUS,VVI1CF
28: COMMON /TIME1/ DT
29: COMMON /TORCCON/ TA13KP
30: COMMON /TQC/ ALAY(20,3)
31: 1 FORMAT (1H1 ,41X,38HVEHICLE PARAMETERS USED FOR SIMULATION )
32: 3 FORMAT(21X,13A6,/,21X,13A6)
33: 4 FORMAT( 120H *****
34: 1*****
35: 2**)
36: 5 FORMAT (42X,1H*,27X,1H*,48X,1H*)
37: 6 FORMAT (1X,40H-----VEHICLE CHARACTERISTICS-----,1X,1H*,2X,
38: 123H---TORQUE CONVERTOR---,2X,1H*,2X,44H-----TRANSMISSI
39: 20N-----,2X,1H*)
40: 7 FORMAT (1X,15HREAR AXLE RATIO,16X,F7.2,3X,1H*,2X,23HSPEED TORQUE
41: 1 1/K**2,2X,1H*,2X,44HGEAR RATIOS SCHEDULE
42: 2 ,2X,1H*)
43: 8 FORMAT (1X, 9HMASS (LB),20X,F8.1,4X,1H*,2X,24HRATIO RATIO (10
44: 1*-4),2H *, 15X,29H ,4X,1H*)
45: 9 FORMAT (1X,25HMASS ON DRIVE WHEELS (LB),4X,F8.1,4X,1H*,27X,1H*,15
46: C , 33H ,1H*)
47: 10 FORMAT (1X,20HFRONTAL AREA (SQ FT),11X,F6.1,4X,1H*,25X,9H * 1ST
48: 1,F6.3,36X, 1H*)
49: 11 FORMAT (1X,31HCOEFFICIENT OF ROLLING FRICTION,F9.4,33X,3H2ND,F6.3
50: 1 ,5X,15HLOCKUP AT ,2X,F5.1,2X,3HMPH)
51: 12 FORMAT (1X,16HDRAG COEFFICIENT,15X,F8.3,34X,3H3RD,F6.3
52: C , 5X,15HUNLOCK AT ,2X,F5.1,2X,3HMPH)
53: 13 FORMAT (1H+,41X,1H*,F7.3,F9.3,F9.4,3H * ,48X,1H*)

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IS SIMULATION PROGRAM

DATE

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54: 14 FORMAT (1X,23HTIRE STATIC RADIUS (FT),8X,F8.3,34X,3H4TH,F6.3
55: C ,5X,15HUPSHIFT 1-2 ,2X,F5.0,2X,3HRPM)
56: 15 FORMAT (1X,26HENGINE INERTIA (LBM-FT**2),5X,F7.2,35X,3H5TH,F6.3
57: C ,5X,15HUPSHIFT 2-3 ,2X,F5.0,2X,3HRPM)
58: 16 FORMAT (1X,25HCG. CONV. TURBINE INERTIA,6X,F7.2,35X,3H6TH,F6.3
59: C ,5X,15HDOWNSHIFT 3-2 ,2X,F5.0,2X,3HRPM)
60: 17 FORMAT (1X,31HTRANSMISSION INERTIA (3RD GEAR),F7.2,35X,5HBEVEL
61: C,F4.2 ,5X,15HDOWNSHIFT 2-1 ,2X,F5.0,2X,3HRPM)
62: 18 FORMAT (1X,17HREAR AXLE INERTIA,14X,F7.2)
63: 19 FORMAT (1X,23HINERTIA OF DRIVE WHEELS,8X,F7.2)
64: 20 FORMAT (1X,26HSTATIC TIRE FRICTION COEF.,5X,F7.2)
65: 21 FORMAT (1X,23HSLIPPING TIRE FRICTION COEF.,3X,F7.2)
66: 22 FORMAT (1X,15HWHEEL BASE (IN),16X,F7.2)
67: 23 FORMAT (1X,29HCENTER OF GRAVITY HEIGHT (IN),2X,F7.2)
68: 24 FORMAT (1X,21HIDLE THROTTLE SETTING,10X,F7.2)
69: 26 FORMAT (1X,28HDELAY TIME AFTER SHIFT (SEC),3X,F7.2)
70: 25 FORMAT (1X,29HTRANSMISSION SHIFT TIME (SEC),2X,F7.2)
71: 27 FORMAT (1X,23HAMBIENT TEMPERATURE (F),8X,F6.1)
72: 28 FORMAT (1X,25HBAROMETRIC PRESSURE (PSI),6X,F9.4)
73: 29 FORMAT (1X,22HAIR DENSITY (LB/CU FT),9X,F9.4)
74: 30 FORMAT (1X,19HENGINE SCALE FACTOR,12X,F8.3)
75: 31 FORMAT (1H ,21HFUEL DENSITY (LB/GAL),10X,F7.2,80X,1H*)
76: 32 FORMAT (42X,14*,F7.3,F9.3,F9.4,3H *)
77: 33 FORMAT (1H ,42H*****28X,49H*)
78: 1*****]
79: 34 FORMAT (1H ,41X,1H*,27X,1H*,3X,20HDRIVESHAFT ROAD LOAD,3H *
80: C ,22X,1H*)
81: 35 FORMAT (1H ,9X,19H--TIRE EXPANSION---,13X,1H*,27X,1H*,3X,20H---TO
82: CRQUE TABLE--- ,2X,1H*,22X,1H*)
83: 36 FORMAT (1H ,9X,19HVEHICLE DRIVESHAFT,13X,1H*,27X,1H*,3X,
84: C 25HVEHICLE ROAD LOAD * ,20X,1H*)
85: 37 FORMAT (1H ,9X,19H SPEED SPEED(RPM),13X,1H*,27X,1H*,5X,
86: C 5HSPEED,5X,6HTORQUE,4X,1H*,22X,1H*)
87: 38 FORMAT (1H ,9X,F6.1,5X,F6.1,15X,1H*,27X,1H*,4X,F6.1,5X,F5.1,5X,
88: C 1H*,22X,1H*)
89: 39 FORMAT (1H ,73X,18HTHIS TABLE IS USED,3X,1H*,22X,1H*)
90: 40 FORMAT (1H ,41X,1H*,27X,1H*,1X,24HRO LOAD EQUATION IS USED,1H*
91: C ,22X,1H*)
92: 41 FORMAT (1H ,42H *****28X,26H*)
93: 1***** )
94: 43 FORMAT (1H+,95X,1H*)
95: 50 FORMAT (1H+,44X,12HDRIVE CYCLE )
96: 51 FORMAT (1H+,44X,12HSTOPS/MILE ,2X,I4)
97: 52 FORMAT (1H+,44X,12HMAX. ACCEL. ,2X,F4.1,1X,6HMPHRS )
98: 53 FORMAT (1H+,44X,12HDECELERATION ,2X,F4.1,1X,6HMPHRS )
99: 54 FORMAT (1H+,44X,12HCRUISE SPEED,2X,F4.1,1X,6HMPH )
00: PRINT 1
01: PRINT 3, (CMM(I),I=1,26)
02: PRINT 4
03: PRINT 6
04: PRINT 5
05: PRINT 7,T8I1GR
06: PRINT 8,VVIM

```

BUS SIMULATION PROGRAM

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107: PRINT 9,VVIMDR
108: MV=1
109: MP=MV-1
110: PRINT 10,VVILFR,TBC1GR(1)
111: I=1
112: TR=AWAY(I,2)
113: SR=AWAY(I,1)
114: SF=AWAY(I,3)*10000.
115: PRINT 11,VVI1RF,TBC1GR(2),ACCL0CK
116: MV=2
117: MP=MV-1
118: PRINT 13,SR,TR,SF
119: PRINT 12,VVI1CD,TBC1GR(3),DECL0CK
120: ASSIGN 81 TO ISTATE
121: 70 CONTINUE
122: GO TO 72
123: 71 CONTINUE
124: 72 CONTINUE
125: MV=MV+1
126: MP=MV-1
127: I=I+1
128: SR=AWAY(I,1)
129: TR=AWAY(I,2)
130: SF=AWAY(I,3)*10000.
131: PRINT 13,SR,TR,SF
132: GO TO ISTATE
133: 81 CONTINUE
134: PRINT 14,VVIDRR,TBC1GR(4),GRMAX(1)
135: ASSIGN 82 TO ISTATE
136: GO TO 70
137: 82 CONTINUE
138: PRINT 15,RIE,TBC1GR(5),GRMAX(2)
139: ASSIGN 83 TO ISTATE
140: GO TO 70
141: 83 CONTINUE
142: PRINT 16,TVIJCT,TBC1GR(6),GRMIN(3)
143: ASSIGN 84 TO ISTATE
144: GO TO 70
145: 84 CONTINUE
146: PRINT 17,TVIJTR,BGRTI9,GRMIN(2)
147: ASSIGN 85 TO ISTATE
148: GO TO 70
149: 85 CONTINUE
150: PRINT 18,TVIJRA
151: ASSIGN 86 TO ISTATE
152: GO TO 70
153: 86 CONTINUE
154: PRINT 19,TVIJTW
155: ASSIGN 87 TO ISTATE
156: GO TO 71
157: 87 CONTINUE
158: PRINT 20,VVIFUM
159: ASSIGN 88 TO ISTATE

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BUS SIMULATION PROGRAM

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160:      GO TO 71
161:      88 CONTINUE
162:      PRINT 21,VVIFUS
163:      ASSIGN 89 TO ISTATE
164:      GO TO 71
165:      89 CONTINUE
166:      PRINT 22,VVISWB
167:      ASSIGN 90 TO ISTATE
168:      GO TO 71
169:      90 CONTINUE
170:      PRINT 23,VVISH
171:      ASSIGN 91 TO ISTATE
172:      GO TO 71
173:      91 CONTINUE
174:      PRINT 24,TIDLE
175:      ASSIGN 92 TO ISTATE
176:      GO TO 71
177:      92 CONTINUE
178:      TST=DT*TBDTMS
179:      PRINT 25,TST
180:      ASSIGN 93 TO ISTATE
181:      GO TO 71
182:      93 CONTINUE
183:      TAS=DT*TBDTH
184:      PRINT 26,TAS
185:      ASSIGN 94 TO ISTATE
186:      GO TO 71
187:      94 CONTINUE
188:      PRINT 27,AVIR
189:      ASSIGN 95 TO ISTATE
190:      GO TO 71
191:      95 CONTINUE
192:      PRINT 28,AVIB
193:      ASSIGN 96 TO ISTATE
194:      GO TO 71
195:      96 CONTINUE
196:      PRINT 29, AVIM
197:      ASSIGN 97 TO ISTATE
198:      GO TO 71
199:      97 CONTINUE
200:      PRINT 30,SCALEF
201:      ASSIGN 98 TO ISTATE
202:      GO TO 71
203:      98 CONTINUE
204:      PRINT 31,FUELWT
205:      ASSIGN 99 TO ISTATE
206:      GO TO 71
207:      99 CONTINUE
208:      ASSIGN 100 TO ISTATE
209:      GO TO 74
210:      73 CONTINUE
211:      GO TO 75
12:      74 CONTINUE

```

SIMULATION PROGRAM

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213:      75 CONTINUE
214:      I=I+1
215:      SR=AWAY(I,1)
216:      TR=AWAY(I,2)
217:      SF=AWAY(I,3)
218: C      PRINT 32,SR,TR,SF
219:      GO TO ISTATE
220:      100 CONTINUE
221:      PRINT 4
222:      ASSIGN 101 TO ISTATE
223:      GO TO 74
224:      101 CONTINUE
225:      PRINT 43
226:      ASSIGN 1001 TO ISTATE
227:      GO TO 74
228:      1001 CONTINUE
229:      PRINT 34
230:      ASSIGN 102 TO ISTATE
231:      GO TO 74
232:      102 CONTINUE
233:      PRINT 35
234:      ASSIGN 103 TO ISTATE
235:      GO TO 74
236:      103 CONTINUE
237:      PRINT 43
238:      ASSIGN 1002 TO ISTATE
239:      GO TO 74
240:      1002 CONTINUE
241:      PRINT 36
242:      PRINT 50
243:      ASSIGN 104 TO ISTATE
244:      GO TO 74
245:      104 CONTINUE
246:      PRINT 37
247:      PRINT 51,NSTOP
248:      ASSIGN 105 TO ISTATE
249:      GO TO 74
250:      105 CONTINUE
251:      PRINT 43
252:      DO 60 K=1,11
253:      V=10*(K-1)
254:      I=I+1
255:      SR=AWAY(I,1)
256:      TR=AWAY(I,2)
257:      SF=AWAY(I,3)
258: C      PRINT 32,SR,TR,SF
259:      PRINT 38,V,T3INV(K),V,TVICRL(K)
260:      IF (K .EQ. 1) CONTINUE;
261:      CPRINT 52,ACEL
262:      IF (K .EQ. 2) PRINT 53,DECEL
263:      IF (K .EQ. 3) PRINT 54,VCRUS
264:      60 CONTINUE
265:      ASSIGN 107 TO ISTATE

```

BUS SIMULATION PROGRAM

256:		GO TO 74
267:	107	CONTINUE
268:		PRINT 43
269:		ASSIGN 108 TO ISTATE
270:		GO TO 74
271:	108	CONTINUE
272:		IF (LOADED) 61,61,62
273:	61	CONTINUE
274:		PRINT 39
275:		GO TO 63
276:	62	CONTINUE
277:		PRINT 40
278:	63	CONTINUE
279:		ASSIGN 109 TO ISTATE
280:		GO TO 74
281:	109	CONTINUE
282:		PRINT 4
283:	64	CONTINUE
284:	C-----	GO TO TOP OF NEXT PAGE
285:	909	FORMAT (1H1)
286:		RETURN
287:		END

3.3.20 Storage and System Computation - RDEPA, EPACALC, EPAVEL

PROGRAM NAMES: RDEPA, EPACALC

TYPE OF SUBROUTINE: Storage and System Computation

DESCRIPTION: RDEPA reads a bus cycle which includes rate of acceleration, velocity of cruise, rate of deceleration, number of stops in cycle, distance of cycle and dwell time of stop. EPACALC calculates the driving cycle velocities at one second intervals. RDEPA then stores them. EPAVEL retrieves the appropriate velocity as a function of time and supplies it to the automatic driver. See Figure 12.

MODELING: Bus cycle velocities are generalized to have four phases, acceleration, cruise, deceleration, and dwell. PEACALC determines the velocity as a function of time and the phase of the cycle.

These cycle velocities are stored in a one dimensional array.

Since they are specified at one second intervals of time, their array location also specifies the cycle time. RDEPA stores two cycle points per word to save core space. This is the reason the velocity array is only dimensioned at 685 words instead of 1370 as would be required for the EPACVS cycle if one point per word was stored.

EPAVEL determines the next cycle point based on time and unpacks the required velocity from the two points per word storage. EPAVEL also prevents Δt from becoming less than a specified value. The next cycle velocity and Δt are returned for use in the automatic drive. See Figure 13.

Any cycle with less than 1370 points at one second intervals can be used.

SUBROUTINE RDEPA

CONSTANTS READ IN:

<u>Name</u>	<u>Symbol</u>	<u>Description</u>
ACEL		Rate of acceleration (mph/sec)
VCRUS		Cruise velocity
DECEL		Rate of deceleration (mph/sec)
NSTOP		Number of stops per route
RTLNGT		Route length
TDWELL		Dwell time at stop

VARIABLES USED:

TA	TA	Time acceleration stops
TC	TC	Time cruising stops
TD	TD	Time deceleration stops
DTD		Time spend deceleration
TE	TE	Time of one cycle
DLNGTH		Distance traveled during one cycle
ITEML, KPLACE, NUEL, KREM		Variables used to pack array

EQUATIONS:

$$\begin{aligned}
 TA &= VCRUS/ACEL \\
 DTD &= VCRUS/DECEL \\
 TC &= (3600. * DLNGTH - .5 (DTD^2 DECEL + TA^2 * ACEL))/VCRUS + TA \\
 TD &= TC + DTD \\
 TE &= TD + TDWELL
 \end{aligned}$$

CONSTANTS STORED:

IVEPA (I)	Array holding target velocity
NVEPA	Length of run (sec)

SUBROUTINE EPACALC

INPUT VARIABLES:

TA	Time acceleration stops
TC	Time cruising stops
TD	Time decelerating stops
TUTIME	Present time interval

OUTPUT VARIABLES:

RVEL	Target velocity at time Tuptime
------	---------------------------------

SUBROUTINE EPAVEL

INPUT VARIABLES:

<u>Program Name</u>	<u>Symbol</u>	<u>Description</u>
TIME	t	Time from start of driving

OUTPUT VARIABLES:

VEPA	V_p	Next required cycle velocity
DELT	Δ_t	Time difference between next cycle point and current time.
ICYEND		Used as a flag to indicate the end of the cycle.

OTHER PROGRAM VARIABLES:

ITEM2 KPLACE KREM,	Variables used to unpack two cycle
ITEM1, IVEL	velocities per word of core.

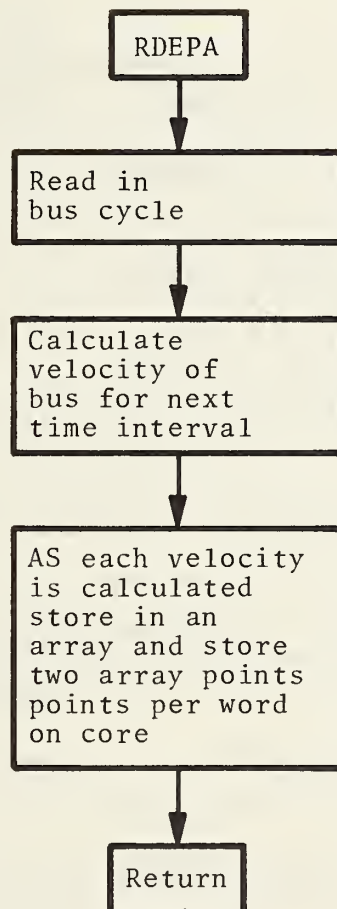


FIGURE 12. RDEPA FLOW DIAGRAM

BUS SIMULATION PROGRAM

```

1: *                                     ***** RDEPA *****
2:      SUBROUTINE RDEPA
3: *
4: *      17 NOV 1976
5: *      READS IN EPA DATA
6: *
7:      COMMON /CONTROL/ GAIN,DELMIN,NVEPA,IVEPA(685)
8: *      ACCEL=ACCELERATION(MPH/SEC)
9: C      VCRUS=CRUISING VELOCITY
10: C      DECEL=DECELERATION FT/SEC**2
11: C      NSTOP=NUMBER OF STOPS
12: C      RTLNGT=ROUTE LENGTH(MILES)
13: C      CALCULATES
14: C      TA TIME ACCELERATION STOPS
15: C      TC TIME CRUISING STOPS
16: C      TD TIME DECELERATING STOPS
17: *      TDWELL=TIME AT THE BUS STOP
18: *      TE=TIME FOR ONE CYCLE =TIDLE+TD
19: *      DLNGTH=LENGTH OF EACH CYCLE(MILES)
20: *
21:      COMMON /EPAASH/ VCRUS,ACEL,DECEL, TDWELL
22:      COMMON /STOPPER/NSTOP
23: *
24:      100 FORMAT(3F8.3,18,2F8.3)
25:      990 FORMAT(17EPA DATA FOLLOWS )
26:      1000 FORMAT(X,5HACEL=,F5.2,2X,7H DECEL=,F5.2,2X,6HVCRUS=,F5.2,2X
27:      1 6HNSTOP=,12,2X,7HRTLNGT=,F5.2,2X,7HTDWELL=,F5.2)
28:      1005 FORMAT(3HTA=,F7.3,2X,3HTC=,F7.3,2X,3HTD=,F7.3,2X,3HTE=,F7.3
29:      1 4HDTD=,F6.3)
30:      1010 FORMAT(X,13(17,2X),17)
31:      1015 FORMAT(6HNVEPA=,15)
32:      1020 FORMAT(12HEND EPA DATA)
33: *
34: C***** READ IN CYCLE INFORMATION
35:      READ 100,ACEL,VCRUS, DECEL,NSTOP,RTLNGT,TDWELL
36:      PRINT 990
37:      PRINT 1000,ACEL,DECEL,VCRUS,NSTOP,RTLNGT, TDWELL
38:      DLNGTH = RTLNGT/FLGAT(NSTOP)
39:      TA=VCRUS/ACEL
40:      DTD=VCRUS/DECEL
41:      TC = 0.5*(DTD*DTD*DECEL + TA*TA*ACEL)
42:      TC = (3600.0*DLNGTH -TC)/VCRUS + TA
43:      TD=TC+DTD
44:      TE = TD + TDWELL
45:      PRINT 1005,TA,TC,TD,TE,DTD
46:      RVEL = 0.0
47:      PTIME = 0.0
48:      DO 5 I = 1,685
49:          IVEPA(I) = 0
50:      5 CONTINUE
51: *
52:      DO 32 I = 1,NSTOP
53:          TR = FLGAT(I)*TE

```

BUS SIMULATION PROGRAM

```

54:      TU = TR - TE
55:      10 CONTINUE
56:      PTIME = PTIME + 1.0
57:      TUTIME = PTIME - TU
58:      CALL EPACALC(RVEL,TUTIME,TA,TC,TD)
59:      NVEL=RVEL*10.
60:      IPTIME = PTIME
61:      KPLACE = IPTIME/2
62:      KREM = IPTIME - 2*KPLACE
63:      IF(KREM) 40,40,20
64:      40 CONTINUE
65:      IVEPA(KPLACE)=NVEL*4096+ITEMP1
66:      GO TO 30
67:      20 CONTINUE
68:      ITEMP1=NVEL
69:      30 CONTINUE
70:      IF(PTIME + 1.0 .GE. TR) GO TO 32
71:      GO TO 10
72:      32 CONTINUE
73:      *
74:      IF(KREM) 34,34,33
75:      33 CONTINUE
76:      IVEPA(KPLACE) = ITEMP1
77:      34 CONTINUE
78:      N = PTIME + 1.0
79:      NN = 0.5*N
80:      PRINT 1015,NN
81:      K = 0
82:      DO 60 J = 1,NN,14
83:      K = K + 14
84:      IF(K - NN) 55,55,50
85:      50 K = NN
86:      55 PRINT 1010,(IVEPA(I),I=J,K)
87:      60 CONTINUE
88:      PRINT 1020
89:      NVEPA=NSTOP*TE
90:      RETURN
91:      END

```

BUS SIMULATION PROGRAM

```

1: *                                     ***** EPACALC *****
2:      SUBROUTINE EPACALC(RVEL,TUTIME,TA,TC,TD)
3: *
4: *      17 NOV 1976
5: C**** RETURNS THE VELOCITY THE VEHICLE MUST REACH IN T+1 SEC.
6: C**** INPUT FROM RDEPA IN COMMON IS VCRUS-CRUISEING SPEED
7: C**** ACCEL-ACCELERATION
8: C**** DECEL-DECELERATION
9: C**** TA-TIME THE ACCELERATION CYCLE ENDS
10: C**** TC-TIME THE CRUISING CYCLE ENDS
11: C**** TD-TIME THE DECELERATION CYCLE ENDS
12: *      TIDLE-TIME AT BUS STOP
13: *      TE-TIME FOR ONE CYCLE =TD + TIDLE
14: *      TUTIME = PTIME - TU FROM RDEPA
15: C
16:      COMMON /EPASH/ VCRUS,ACEL,DECEL, TDWELL
17: *
18:      IF(TUTIME-TA) 10,20,20
19:      20 IF(TUTIME-TC) 30,40,40
20:      40 IF(TUTIME-TD) 50,60,60
21: C**** ACCELERATING
22:      10 RVEL=RVEL+ACEL
23:      GOTO 90
24: C**** LETS CRUISE
25:      30 RVEL=VCRUS
26:      GOTO 90
27: C**** DECELERATE
28:      50 CONTINUE
29:      RVEL=RVEL-DECEL
30:      IF(RVEL) 60,90,90
31: C**** STOP THE BUS
32:      60 CONTINUE
33:      RVEL=0
34:      90 CONTINUE
35:      RVEL=RVEL*10+0
36:      RETURN
37:      END

```

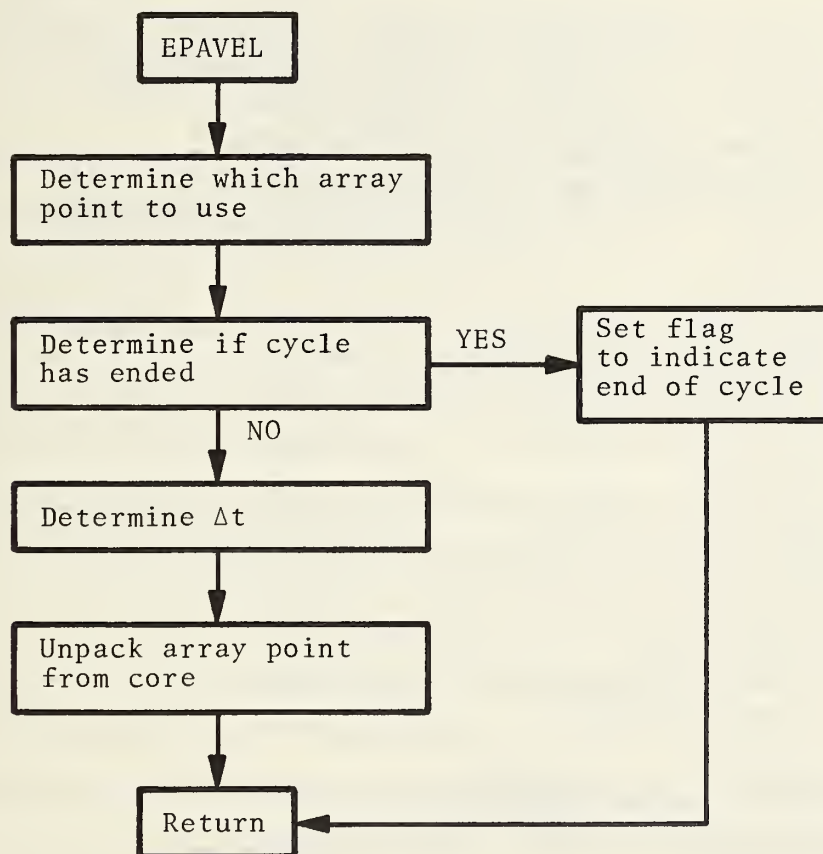


FIGURE 13. EPAVEL FLOW DIAGRAM

BJS SIMULATION PROGRAM

```

1: *                               **** EPAVEL ****
2:   SUBROUTINE EPAVEL (TIME,VEPA,ICYEND,DELT)
3: C***** RETURNS VEPA AND DELT AND ICYEND
4: C***** VEPA THE NEXT CYCLE TARGET VELOCITY
5: C***** DELT THE AMOUNT OF TIME TO REACH THE CYCLE VELOCITY
6: C***** ICYEND FLAG TO INDICATE THE END OF THE RUN
7:   COMMON /CONTROL/ GAIN,DELMIN,NVEPA,IVEPA(685)
8:   I=TIME
9:   II=I+1
10:  16 CONTINUE
11:   DELT=FLOAT(II)-TIME
12:   IF(DELT-DELMIN)15,10,10
13:  15 II=II+1
14:   IF(II-NVEPA)7,7,6
15:  6 CONTINUE
16:   II=NVEPA
17:   ICYEND=1
18:   GO TO 10
19:  7 CONTINUE
20:   GO TO 16
21:  10 CONTINUE
22:   KPLACE=II/2
23:   KREM=II-2*KPLACE
24:   IF(KREM)35,35,30
25:  30 CONTINUE
26:   ITEMP1=IVEPA(KPLACE+1)
27:   ITEMP2=(ITEMP1/4096)*4096
28:   IVEL=ITEMP1-ITEMP2
29:   GO TO 40
30:  35 CONTINUE
31:   ITEMP1=IVEPA(KPLACE)
32:   IVEL=ITEMP1/4096
33:  40 CONTINUE
34:   VEPA=IVEL/10.
35:   RETURN
36:   END

```

3.3.21 Rear Axle Efficiency - RAEFF

PROGRAM NAME: RAEFF

TYPE OF SUBROUTINE: System Computation

DESCRIPTION: This subroutine calculates the rear axle efficiency as a function of driveshaft torque and speed. It returns the rear axle output torque for use in the vehicle dynamics subroutine (VEDYN).

MODELING: This model is basically similar to the transmission efficiency model (see TREFF) except for the manner in which the data were curve fit.

A plot of the efficiency curves as a function of torque at constant speed is given by Figure 14. Since all values for efficiency are between 0.9 and 1.00, each data point is modeled as 0.9 plus a change $\Delta\eta$.

$$\eta = 0.90 + \Delta\eta$$

The $\Delta\eta$ is calculated using a second degree polynomial as a function of driveshaft speed.

$$\eta = 0.90 + C_1 + C_2 N_{DS} + C_3 N_{DS}^2$$

The three coefficients, C_1 , C_2 , C_3 , are modeled over the torque range using polynomial fits up to degree 6. The resulting curve fit is a three-dimensional surface as shown in Fig. 15.

When the driveshaft torque falls below the lower boundary to which the curve fit can be reasonably extended based on available data, the efficiency is exponentially interpolated between the efficiency at the boundary for the given speed and zero (Eqs. 2 and 3). If

the driveshaft torque is beyond the range to which the curve fit can be reasonably extended, the efficiency is assumed to be the same as that at the boundary. Since the latter case happens very seldom, the sole purpose of the provision is to prevent incongruities in the program if it does occur.

A table of rear axle efficiencies generated by the program is presented in Fig.16.

It may be noted from the flow and block diagrams in Figs. 17 and 18 that the driveshaft torque can be changed a number of times in this subroutine. These are for purposes of calculating the efficiency only, and the original value of driveshaft torque is restored at the end of the program through use of a dummy variable.

EQUATIONS:

$$1) \quad \eta_{RA} = f(N_{DS}, T_{DS})$$

For driveshaft torques below range of $f(N_{DS}, T_{DS})$,

$$2) \quad K = \frac{\ln(1 - \eta_{RA_L})}{T_{DS_L}}$$

$$3) \quad \eta_{RA} = 1. - \exp(K \cdot T_{DS})$$

$$4) \quad T_{RA} = T_{DS} \cdot \eta_{RA} \cdot CR_{RA}$$

INPUT VARIABLES:

<u>Program Name</u>	<u>Symbol</u>	<u>Description</u>
T9IN	N_{DS}	Driveshaft speed
T9IC	T_{DS}	Driveshaft torque
T9I1GR	GR_{RA}	Rear axle ratio equivalent

OUTPUT VARIABLES:

T9I1	η_{RA}	Rear axle efficiency
T9OC	T_{RA}	Rear axle output torque

VARIABLES WHICH MUST BE STORED IN MEMORY

None

OTHER PROGRAM VARIABLES:

T9DC	T_{DS_D}	Dummy driveshaft torque variable
T9DN	N_{DS_D}	Dummy driveshaft speed variable
T9DCL	T_{DS_L}	Torque at lower boundary of data
T9DCU	T_{DS_U}	Torque at upper boundary of data
INTERP	FLAG	Flag set to determine if interpolation is necessary

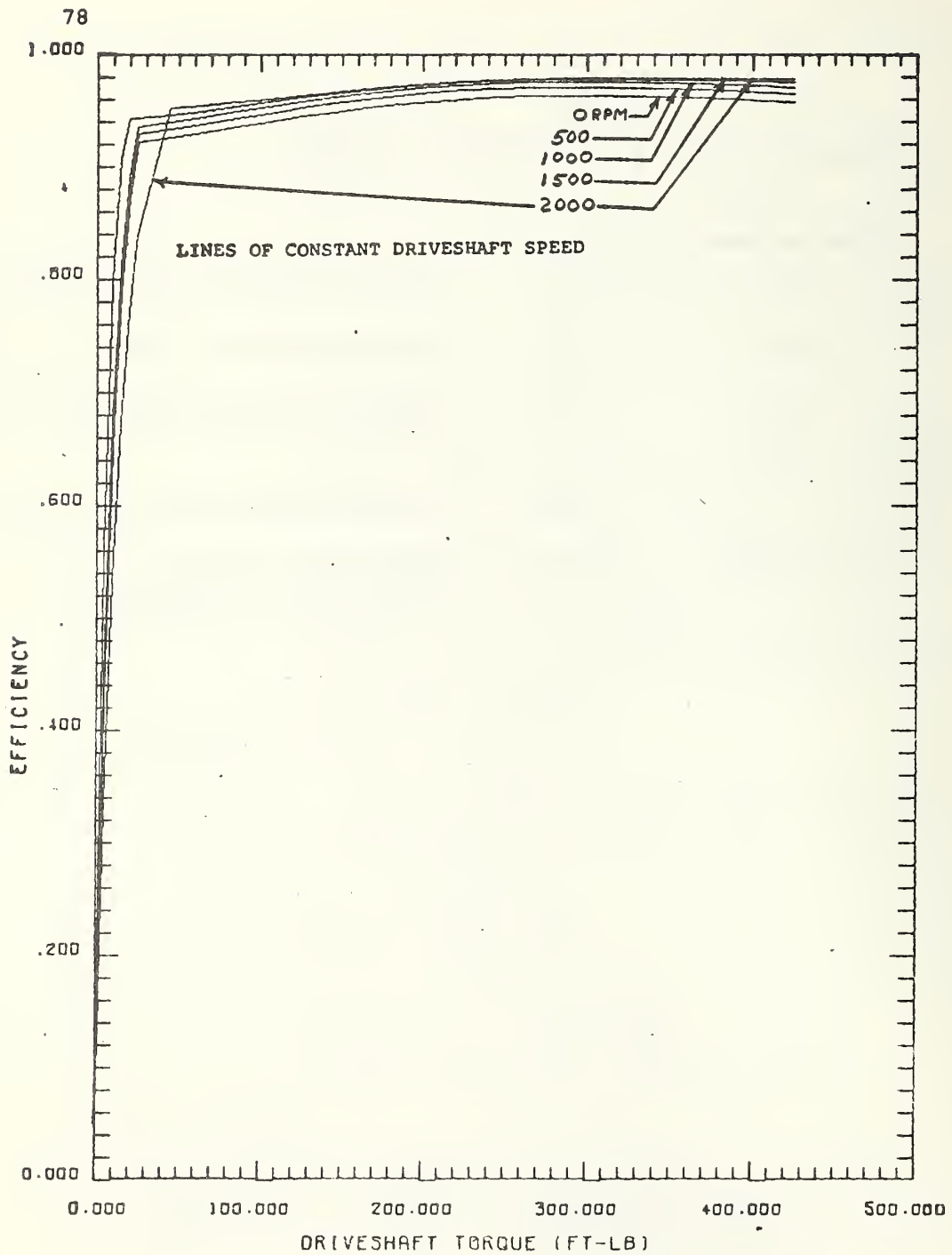


FIGURE 14. REAR AXLE EFFICIENCY

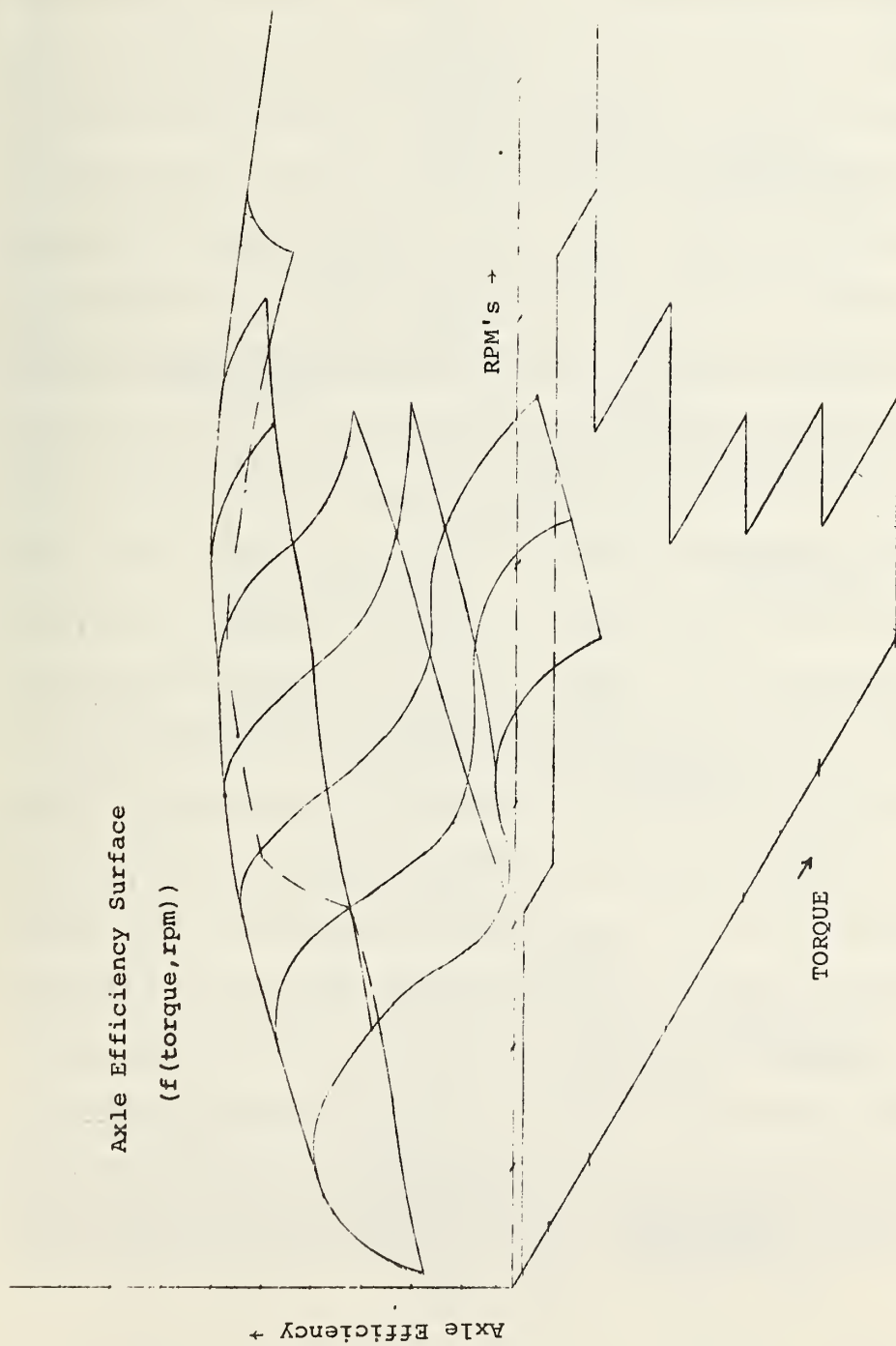


FIGURE 15. REAR AXLE EFFICIENCY VS TORQUE AND RPM

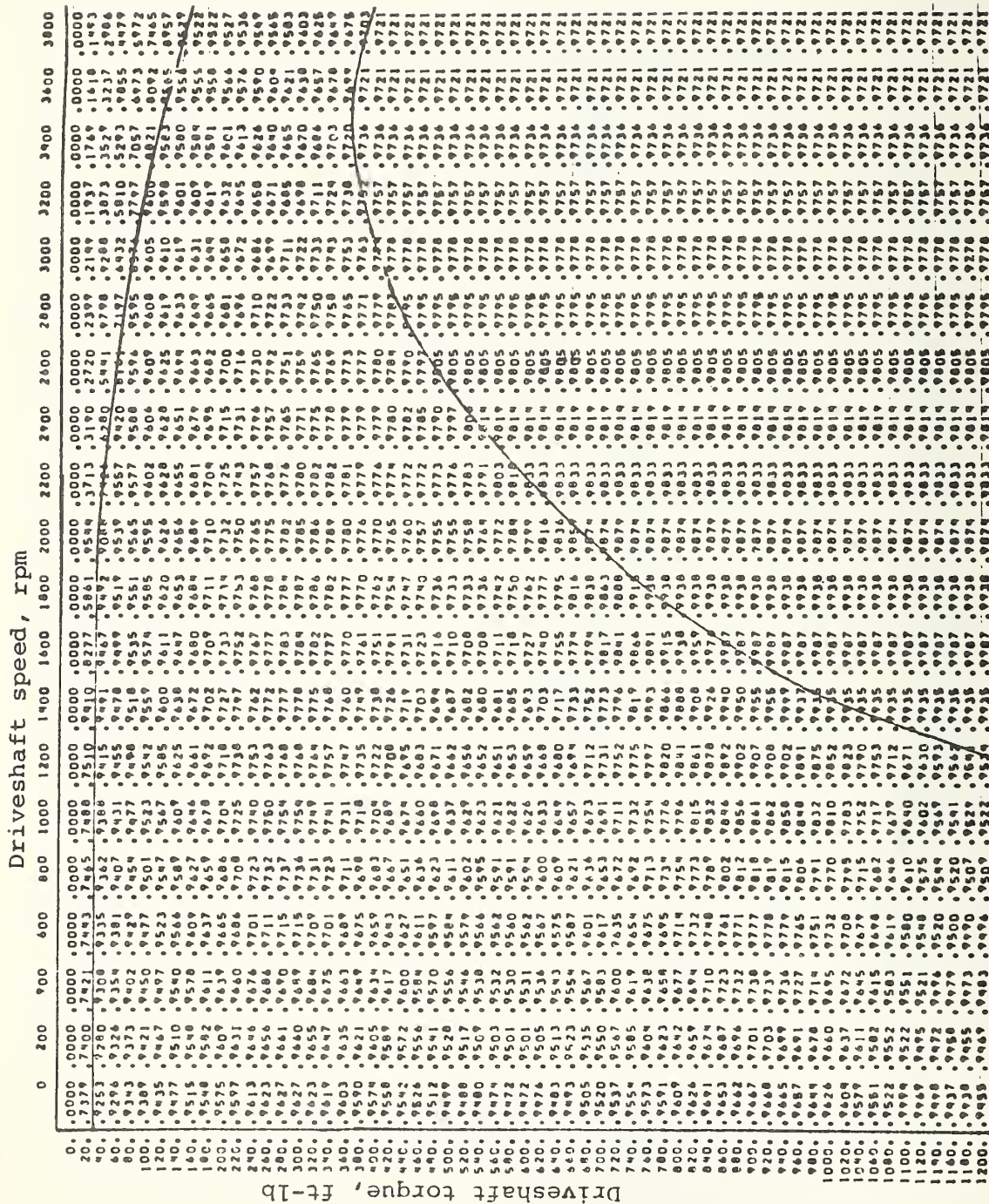


FIGURE 16. REAR AXLE EFFICIENCIES GENERATED BY RAEFF (THE CURVED LINES INDICATE THE LIMITS OF EXPERIMENTAL DATA.)

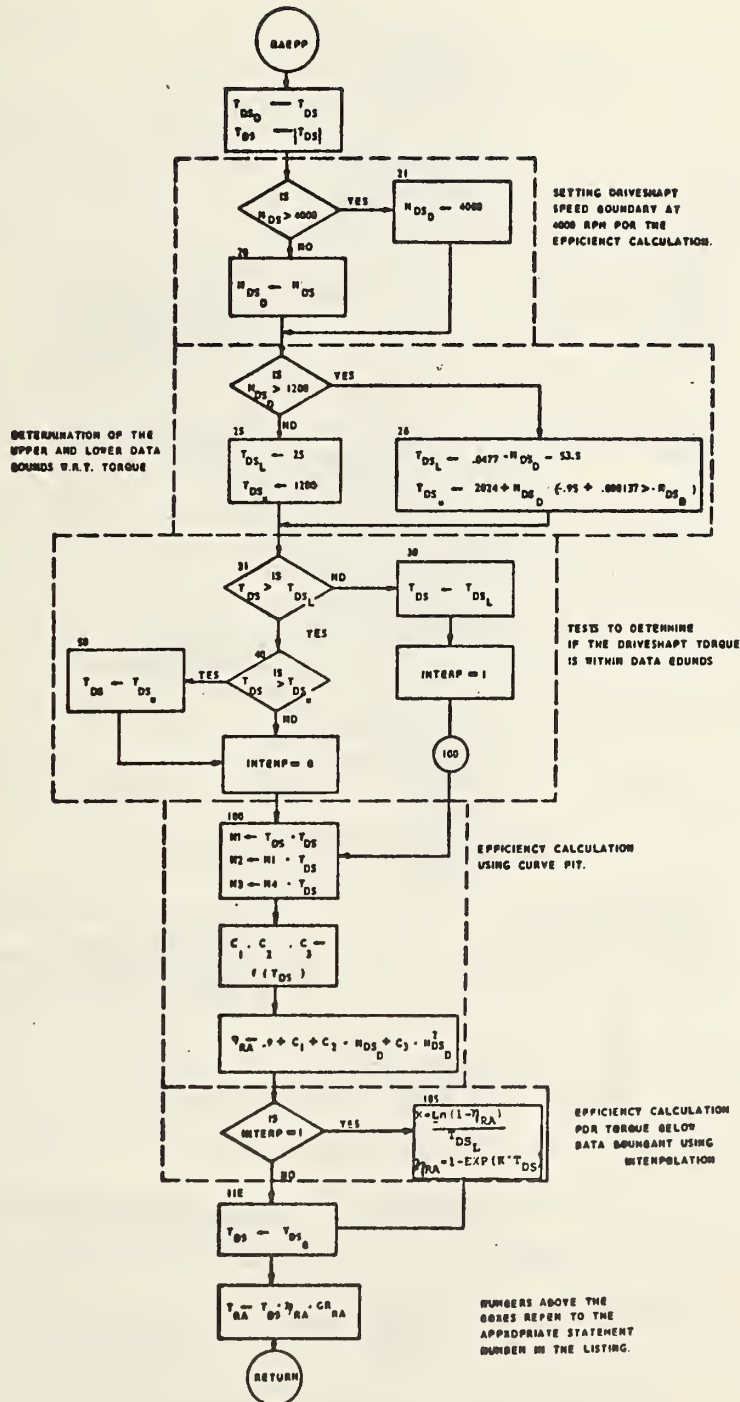


FIGURE 17. REAR AXLE EFFICIENCY FLOW DIAGRAM

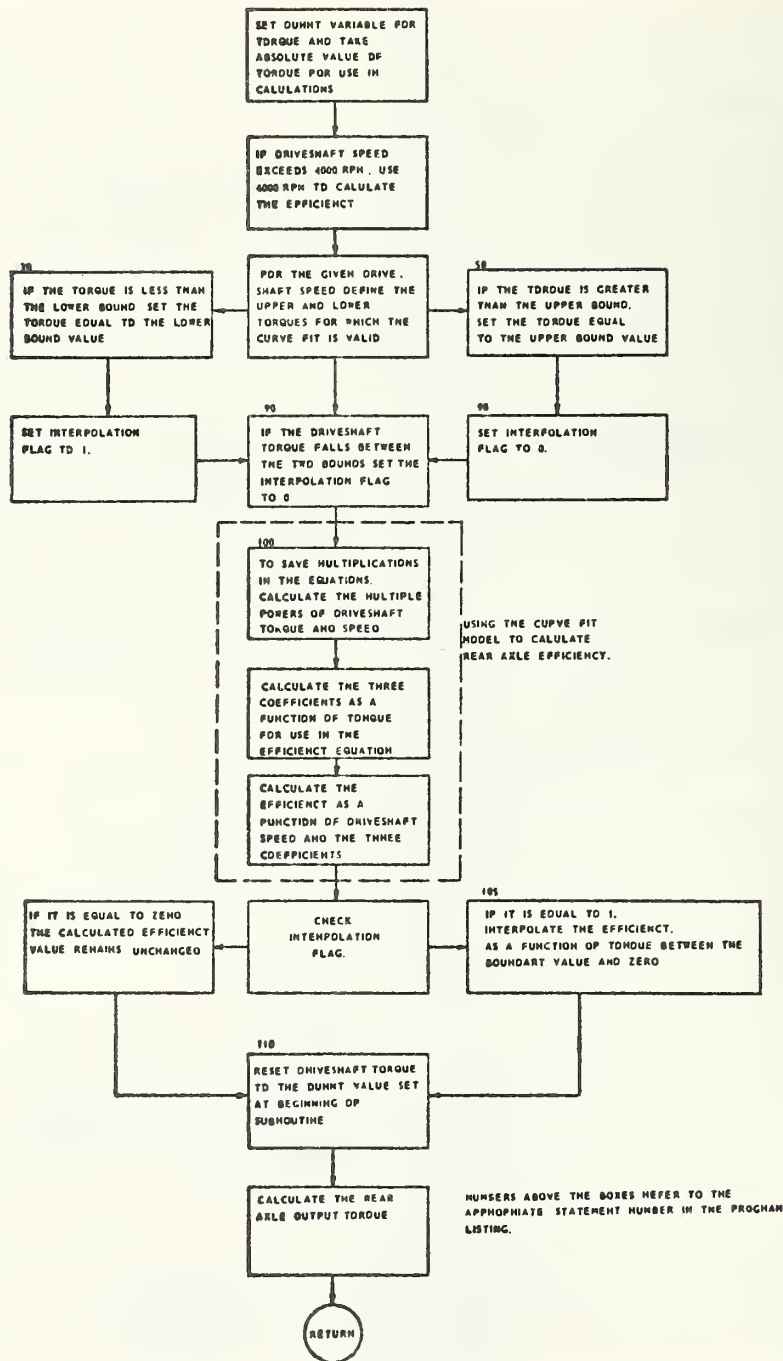


FIGURE 18. REAR AXLE EFFICIENCY BLOCK DIAGRAM

BUS SIMULATION PROGRAM

D

```

1: *                                     **** RAEFF ****
2:   SUBROUTINE RAEFF(T9IC,T9IN,T9I1GR,T9DC,T9I1)
3: C---- SUBROUTINE TO DETERMINE REAR AXLE EFFICIENCY.
4: C---- DAN KAPellen 10/73, REVISED 2/74
5: C*****
6: C---- THIS SUBROUTINE CALCULATES THE REAR AXLE EFFICIENCY AS A FUNCTION
7: C---- OF DRIVESHAFT TORQUE AND SPEED. IT RETURNS THE REAR AXLE OUTPUT TO
8: C---- BE USED IN THE VEHICLE DYNAMICS SUBROUTINE (VEDYN). THE VARIABLES I
9: C---- NPUT PROGRAM ARE AS FOLLOWS,
10: C---- INPUT VARIABLES-----
11: C---- T9IC-DRIVESHAFT TORQUE
12: C---- T9IN-DRIVESHAFT SPEED.
13: C---- T9I1GR-EQUIVALENT REAR AXLE RATIO.
14: C---- OUTPUT VARIABLES-----
15: C---- T9I1-REAR AXLE EFFICIENCY.
16: C---- T9DC-REAR AXLE OUTPUT TORQUE.
17: C---- OTHER PROGRAM VARIABLES-----
18: C---- T9DC-DUMMY DRIVESHAFT TORQUE, USED TO PRESERVE VALUE OF T9IC.
19: C---- T9DN-DUMMY DRIVESHAFT SPEED, USED TO PRESERVE VALUE OF T9IN.
20: C---- T9DCL-LOWEST TORQUE AT WHICH CURVE FIT IS CONSIDERED VALID.
21: C---- T9DCU-HIGHEST TORQUE AT WHICH CURVE FIT IS CONSIDERED VALID.
22: C---- INTERP-FLAG SET TO INDICATE INTERPOLATION IS NECESSARY BETWEEN C
23: C*****
24: C---- SET DUMMY DRIVESHAFT TORQUE.
25:   T9DC=T9IC
26: C---- USE THE ABSOLUTE VALUE OF DRIVESHAFT TORQUE TO CALCULATE THE EFF
27:   T9IC=ABS(T9IC)
28: C---- IF DRIVESHAFT SPEED EXCEEDS 4000 RPM, USE 4000 RPM TO CALCULATE
29:   IF(T9IN-4000.)20,20,21
30:   21 T9DN=4000.
31:   GO TO 22
32:   20 CONTINUE
33: C---- SET DUMMY DRIVESHAFT SPEED.
34:   T9DN=T9IN
35:   22 CONTINUE
36: C---- DEFINE THE UPPER AND LOWER TORQUES FOR WHICH THE CURVE FIT IS VA
37:   IF(T9DN-1200.)25,25,26
38:   25 T9DCL=25.
39:   T9DCU=1200.
40:   GO TO 31
41:   26 T9DCL=.0477*T9DN-53.5
42:   T9DCU=2024.+.T9DN*(-.95 +.000137*T9DN)
43:   31 CONTINUE
44: C---- IF THE TORQUE IS LESS THAN THE LOWER BOUND, SET THE TORQUE EQUAL
45: C---- TO LOWER BOUND VALUE OF TORQUE.
46:   IF(T9IC-T9DCL)30,40,40
47:   30 T9IC=T9DCL
48: C---- THEN SET THE INTERPOLATION FLAG TO 1.
49:   INTERP=1
50:   GO TO 100
51:   40 CONTINUE
52: C---- IF THE TORQUE IS GREATER THAN THE UPPER BOUND, SET IT EQUAL TO TI
53:   IF(T9IC-T9DCU)90,90,50

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2. SIMULATION PROGRAM

```

55: 50 T9IC=T9DCU
56: C---- IF THE D.S. TORQUE FALLS BETWEEN THE TWO BOUNDS SET THE INT. F
57: 90 INTERP=0
58: 100 CONTINUE
59: C---- TO SAVE MULTIPLICATIONS, CALCULATE THE MULTIPLE POWERS OF D.S. TO
60: H1=T9IC*T9IC
61: H2=T9IC*H1
62: H3=T9IC*H2
63: H4=T9IC*H3
64: H5=T9IC*H4
65: H6=T9DN*T9DN
66: C---- CALCULATE THE THREE COEFFICIENTS AS A FUNCTION OF TORQUE.
67: C1=1.867E-2+(1.1314E-4)*T9IC+(1.6491E-6)*H1+(-9.0929E-9)*H2
68: 1 + (1.688E-11)*H3+(-1.3281E-14)*H4+(3.7756E-18)*H5
69: C2=1.1143E-5+(7.8431E-8)*T9IC+(-2.9137E-10)*H1+(3.7934E-13)*H2
70: 2 + (-1.6109E-16)*H3
71: C3=2.3793E-9+(-7.6401E-11)*T9IC+(2.418E-13)*H1+(-2.4492E-16)*H2
72: 3 + (7.8702E-20)*H3
73: C---- CALCULATE THE EFFICIENCY AS A FUNCTION OF D.S. SPEED AND THE 3 C
74: T9I1=C1+C2*T9DN+C3*H6+.90
75: C---- CHECK THE INTERPOLATION FLAG.
76: IF (INTERP) 110, 110, 105
77: C---- IF NOT, THEN INTERPOLATE THE EFFICIENCY AS A FUNCTION OF D.S.
78: BETWEEN ZERO EFF. AND THE EFF. CALCULATED AT THE CURVE FIT BOUN
79: 105 CONTINUE
80: IF (1.00-T9I1) 106, 107, 107
81: 106 CONTINUE
82: T9I1=1.00
83: 107 CONTINUE
84: C---- THIS INTERPOLATION USES AN EXPONENTIAL, FIRST CALCULATE THE CON
85: USED IN THE EXPONENTIAL BASED ON THE TORQUE AND EFF AT THE CURV
86: SK=ALOG(1.-T9I1)/T9DCL
87: C---- THEN CALCULATE THE INTERPOLATED EFFICIENCY.
88: T9I1=1.-EXP(SK*ABS(T9DC))
89: C---- RESET THE DRIVESHAFT TORQUE TO ITS ORIGINAL VALUE.
90: 110 T9IC=T9DC
91: C---- CALCULATE THE REAR AXLE OUTPUT TORQUE.
92: T9OC=T9IC*T9I1*T9I1GR
93: RETURN
94: END

```

3.3.22 Subroutine to Interpolate with Equally Spaced Grid Points -
RIXON 2, RIXON 22

SUBROUTINE NAME: RIXON2 and RIXON22

TYPE OF SUBROUTINE: System Computation

DESCRIPTION: The subroutine RIXON2 is used to evaluate a function of two variables from a table of function values at equally spaced grid points. The steady state torque as a function of engine speed and throttle setting is one such function. Fuel consumption as a function of steady state torque and engine speed is another function of this type.

MODELING: The function values are stored at the intersections of a lattice network whose x and y increments are different constants. The four function values at the corners of the rectangle which surround the input point are found. Interpolation is used in the x direction to obtain two function values which bracket the function value at the input point in the y direction. Then linear interpolation is used again to approximate the function value at the input point. If the input point exceeds the limit of the lattice network, extrapolation from the closest rectangle is used.

EQUATIONS: S/L

INPUT VARIABLES: X - the X coordinate at which the function is to be evaluated
Y - the Y coordinate at which the function is to be evaluated

OUTPUT VARIABLES: Z - the approximated value of the function at the point (X,Y)

OTHER VARIABLES: IA(50,17) - the table of function values

at the intersections of the
lattice network

NOTE: The first row of IA contains information describing how the data are stored in the rest of IA. The second row of IA and the first column of IA, save for the element in the first row, do not contain function values at the grid points.

IA(1,1) is the minimum X value

IA(1,2) is the maximum X value

IA(1,3) is one less than the number of
X values

IA(1,4) is the minimum Y value

IA(1,5) is the maximum Y value

IA(1,6) is the one less than the number
of Y values

IA(1,7) is the Z value multiplier

IA(1,8) is the Z value divisor

PROGRAM VARIABLES: DELX - X constant increment
DELY - Y constant increment
CONSX - X interpolation factor
CONSY - Y interpolation factor
I1 - The index for least Y lattice
points
I2 - The index for greatest Y lattice
points
Z11 - Function value at least S, least
Y lattice points
Z12 - Function value at least Y, greatest
X lattice points
Z21 - Function value at greatest Y,
least X lattice points
Z22 - Function value at greatest Y,
greatest X lattice points

BUS SIMULATION PROGRAM

```

1: *                                     **** RIXON2 ****
2:      SUBROUTINE RIXON2(X,Y,Z,IA)
3: C---- SUBROUTINE TO INTERPOLATE EQUALLY SPACED POINTS
4: C---- R.R.RADTKE 2/19/74
5:      DIMENSION IA(55,17)
6:      RMINX=IA(1,1)
7:      RMAXX=IA(1,2)
8:      RNINCX=IA(1,3)
9:      RMINY=IA(1,4)
10:     RMAXY=IA(1,5)
11:     RNINCY=IA(1,6)
12:     RMULZ=IA(1,7)
13:     RDIVZ=IA(1,8)
14:     MXINC=IA(1,3)-1
15:     MYINC=IA(1,6)-1
16: C
17: C
18: C---- COMPUTE X INDICES
19:     DELX=(RMAXX-RMINX)/RNINCX
20:     J1=(X-RMINX)/DELX+1.
21:     IF (J1-1)5,10,10
22:     5 J1=1
23:     10 CONTINUE
24:     IF (J1-MXINC)20,20,15
25:     15 J1=MXINC
26:     20 CONTINUE
27:     CONSX=(X-(J1-1)*DELX-RMINX)/DELX
28: C---- X DATA STARTS IN COLUMN 2
29:     J1=J1+1
30:     J2=J1+1
31: C
32: C
33: C---- COMPUTE Y INDICES
34:     DELY=(RMAXY-RMINY)/RNINCY
35:     I1=(Y-RMINY)/DELY+1.
36:     IF (I1-1)25,30,30
37:     25 I1=1
38:     30 CONTINUE
39:     IF (I1-MYINC)40,40,35
40:     35 I1=MYINC
41:     40 CONTINUE
42:     CONSY=(Y-(I1-1)*DELY-RMINY)/DELY
43: C---- Y DATA STARTS IN ROW 3
44:     I1=I1+2
45:     I2=I1+1
46: C
47: C
48: C---- Z INTERPOLATION
49:     Z11=IA(I1,J1)
50:     Z12=IA(I1,J2)
51:     Z21=IA(I2,J1)
52:     Z22=IA(I2,J2)
53:     Z1=Z11+CONSX*(Z12-Z11)

```

BUS SIMULATION PROGRAM

54:	Z2=Z21+CONSx*(Z22-Z21)
55:	Z=Z1+CONSx*(Z2-Z1)
56:	Z=Z*RMULZ/RDIVZ
7:	RETURN
58:	END

3.3.23 Subroutine to Account for Effect of Tire Expansion - TGG15

PROGRAM NAME: TGG15

TYPE OF SUBROUTINE: System Computation

DESCRIPTION: This program determines a "corrected" drive-shaft speed and an "equivalent" rear axle ratio based on vehicle speed.

MODELING: As vehicle speed increases, centrifugal force causes the tire diameter to increase. Therefore, for a given vehicle speed, the drive-shaft speed is less and the driveshaft torque is greater than it would be if the tire maintained the same radius.

A table of driveshaft speeds obtained experimentally at 10-mph increments is read into memory in the initialization subroutine (INICON). The tire expansion subroutine, based on vehicle speed, linearly interpolates between the stored points to obtain the corrected or actual driveshaft speed. Although the tire expansion is not linear (it is a function of ω^2) linear interpolation is sufficient since the change in tire radius is not large (see Fig. 19).

An equivalent rear axle ratio is calculated rather than a new tire rolling radius because this makes the effect of tire expansion easier to recognize when analyzing results.

Since data are generally not available (or necessary) over 100 mph, this model is only

accurate to 100 mph. To keep the program running in the event 100 mph is exceeded, the equivalent rear axle ratio is assumed to be the same as the iteration before 100 mph was exceeded. The driveshaft speed is then calculated on this basis. This is the function of statement number 15 in the program: listing and flow diagram (Fig. 20).

EQUATIONS:

$$N_{DSU} = \frac{\frac{5280}{60} V GR_{RA}}{2R_T}$$

$$N_{DS} = f(V)$$

$$GR_{RA} = GR_{RA} \frac{N_{DS}}{N_{DSU}}$$

INPUT VARIABLES:

<u>Program Name</u>	<u>Symbol</u>	<u>Description</u>
VVOS	V	Vehicle speed

OUTPUT VARIABLES:

T9IN	N_{DS}	Actual driveshaft speed
T9I1GR	GR_{RA}	Equivalent rear axle ratio
T8I1GR	GR_{RA}	Nominal rear axle ratio

VARIABLES TO BE STORED IN MEMORY:

T8INV(J)	N_{DSJ}	Table of driveshaft speeds
VVIDRR	R_T	Tire radius

OTHER PROGRAM VARIABLES:

<u>Program Name</u>	<u>Symbol</u>	<u>Description</u>
T8DN	N_{DS}	Uncorrected driveshaft speed
T8DNHI	N_H	Upper interpolation point
T8DNLO	N_L	Lower interpolation point
DIFF	Diff	Difference between current vehicle speed and vehicle speed at lower interpolation point.

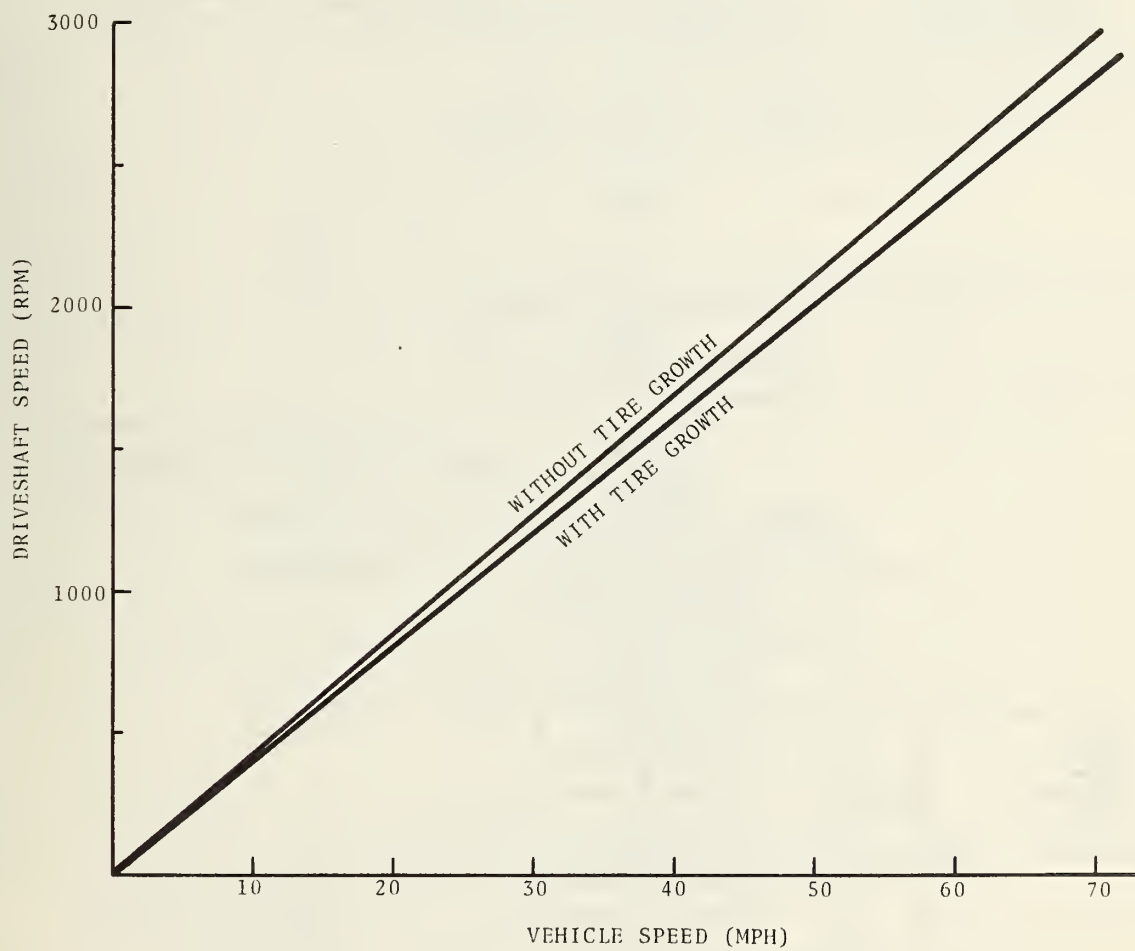
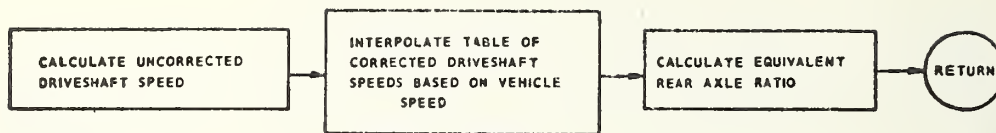


FIGURE 19. VEHICLE VS DRIVESHAFT SPEED



Tire Growth Flow Diagram

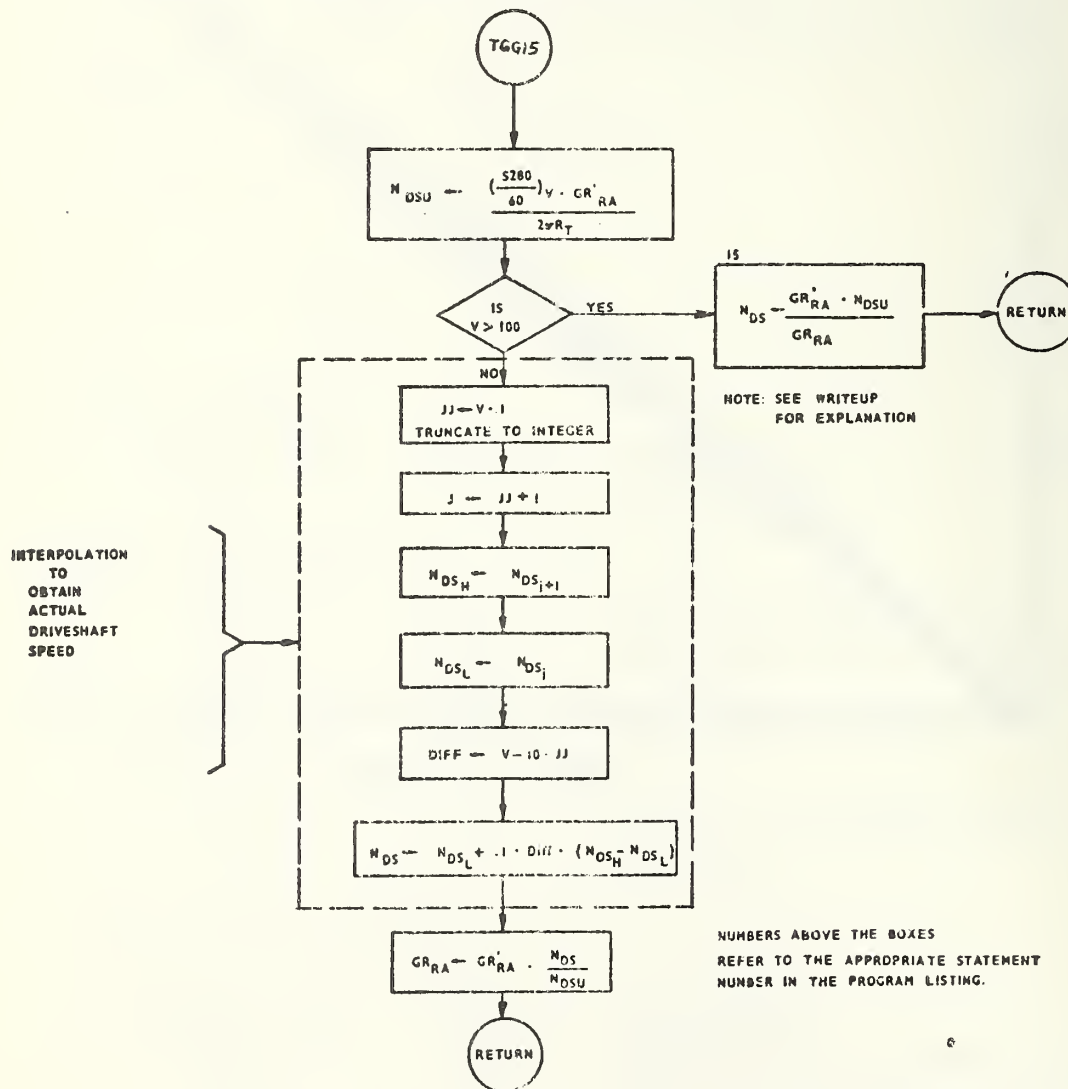


FIGURE 20. BLOCK AND FLOW DIAGRAM FOR TIRE GROWTH

```

1: *
2: C---- SUBROUTINE TO DETERMINE EFFECTIVE REAR AXLE RATIO AND D.S. SPEED
3: SUBROUTINE TGG15(VV0S,T9IN,T9I1GR)
4: COMMON /DSSPD/ T8INV(12)
5: COMMON /RGRTIO/ T8I1GR
6: COMMON /TIRE/ VVIDRR,VVIFUM,VVIFUS,VVIICF
7: C*****
8: C---- THIS SUBROUTINE DETERMINES A 'CORRECTED' DRIVESHAFT SPEED AND AN
9: C---- 'EQUIVALENT' REAR AXLE RATIO BASED ON A TABLE OF DRIVESHAFT SPEED
10: C---- AS A FUNCTION OF VEHICLE SPEED OBTAINED FROM EXPERIMENTAL DATA.
11: C---- THE PROGRAM VARIABLES ARE AS FOLLOWS.
12: C----- INPUT VARIABLES-----
13: C ----T8I1GR BEVEL GEAR RATIO
14: C ----VV0S---VEHICLE SPEED.
15: C-----PUT PUT VARIABLES-----
16: C----T9IN---'CORRECTED' DRIVESHAFT SPEED TAKING INTO ACCOUNT TIRE GRW
17: C----T9I1GR---EQUIVALENT REAR AXLE RATIO.
18: C-----PROGRAM CONSTANTS-----
19: C----T8INV(J)-TABLE OF DRIVESHAFT SPEEDS AS A FUNCTION OF VEHICLE SPEED
20: C----VVIDRR---TIRE RADIUS.
21: C----T9I1GR---NOMINAL REAR AXLE RATIO.
22: C-----OTHER PROGRAM VARIABLES-----
23: C----T8DN---UNCORRECTED DRIVESHAFT SPEED.
24: C----T8DNHI---UPPER INTERPOLATION DRIVESHAFT SPEED.
25: C----T8DNLO---LOWER INTERPOLATION DRIVESHAFT SPEED.
26: C----DIFF---DIFFERENCE BETWEEN CURRENT VEHICLE SPEED AND VEHICLE
27: C----SPEED AT LOWER INTERPOLATION POINT.
28: C*****
29: C---- CALCULATE THE UNCORRECTED DRIVESHAFT SPEED.
30: T8DN=14.00545*VV0S*T8I1GR /VVIDRR
31: C---- TEST IF THE VEHICLE SPEED EXCEEDS THE RANGE OF THE TABLE.
32: IF (VV0S-100.)5,5,15
33: 5 CONTINUE
34: C---- DETERMINE INDICES FOR UPPER AND LOWER INTERPOLATION SPEEDS.
35: JJ=VV0S*.1
36: C---- DETERMINE THE DRIVESHAFT SPEEDS AT THE UPPER AND LOWER INTERPOLATI
37: J=JJ+1
38: T8DNHI=T8INV(J+1)
39: T8DNLO=T8INV(J)
40: DIFF=VV0S-10.*JJ
41: C---- INTERPOLATE TABLE FOR CORRECTED DRIVESHAFT SPEED.
42: T9IN=T8DNLO+.1*DIFF*(T8DNHI-T8DNLO)
43: IF (T9IN-.1) 11,11,10
44: C---- CALCULATE THE 'EQUIVALENT' REAR AXLE RATIO BASED ON THE RATIO
45: C---- OF THE CORRECTED TO UNCORRECTED DRIVESHAFT SPEED.
46: 10 T9I1GR=T8I1GR*T9IN/T8DN
47: GO TO 998
48: 11 T9I1GR=T8I1GR
49: GO TO 998
50: 15 CONTINUE
51: T9IN=T9I1GR*T8DN/T8I1GR
52: 998 CONTINUE
53: RETURN
54: END

```

3.3.24 Torque Converter - TQCONV, VELTERP

PROGRAM NAMES: TQCONV and VELTERP

TYPE OF SUBROUTINE: System Computation

DESCRIPTION: This subroutine calculates the square of the inverse input size factor and the torque ratio as functions of speed ratio. The converter input torque and converter output torque are then calculated for use in subsequent subroutines. See Figure 21.

If the converter is locked the speed ratio and torque ratio are retrieved from memory in lookup.

MODELING: The speed ratio is determined by dividing the converter output speed by the converter input speed. The converter output speed is determined from the current vehicle speed and gear ratio, which are calculated by other routines. This speed ratio is used to calculate the inverse input size factor and the torque ratio.

To use this subroutine it is necessary to input a table of the torque ratio and the square of the inverse input size factor as a function of speed ratio based on experimental data.

This array called AWAY holds the speed ratio, torque ratio and inverse size factor.

VELTERP chains through the speed ratios and finds where the calculated speed ratio falls. A linear interpolation is then used to determine the torque ratio and the inverse size factor.

The torque converter input torque is calculated. This is divided by the Bevel Gear

ratio to determine the engine torque. The torque converter output torque is then determined.

If the torque converter is locked, the torque ratio and speed ratio is retrieved from memory and the engine output torque, torque converter, input torque and output torque are calculated.

Figure 22 shows a typical curve of torque ratio as a function of speed ratio and Fig. 23 is a curve of the square of the inverse size factor as a function of speed ratio.

EQUATIONS USED: 1) For speed ratio

$$SR = N_{CO}/N_{CI}$$

2) For input torque

$$T_{CI} = N_{CI}^2 * 1/K_I^2$$

3) For output torque

$$T_{CO} = T_{CI} * TR$$

4) For flywheel torque if unlocked

$$T_E = T_{CI}/GR_{BG}$$

5) For flywheel torque if locked

$$T_E = T_{SS} - T_A$$

<u>VARIABLE NAME</u>	<u>SYMBOL</u>	<u>MEANING</u>
ACTORQ	T_A	Accessory Torque
BAON	N_{CI}	Converter input speed
LOCK		Indicates if converter's locked
SSTORQ	T_{SS}	Engine torque
TAON	N_{CO}	Converter output speed

OUTPUT VARIABLES

BAOC	T_{CI}	Converter input torque
PAOC	T_E	Flywheel torque
TAOC	T_{CO}	Converter output torque

TA01TR	TR	Converter torque ratio
TAI1ST	SR	Converter speed ratio

CONSTANTS ACCESSED

<u>Variable Name</u>	<u>Symbol</u>	<u>Meaning</u>
BGRT10	GR_{BG}	Bevel gear ratio
AWAY		Table holds torque ratio and inverse size factor as a function of speed ratio

LOCAL VARIABLES

TAI3IK	$1/K_I^2$	Inverse size factor
--------	-----------	---------------------

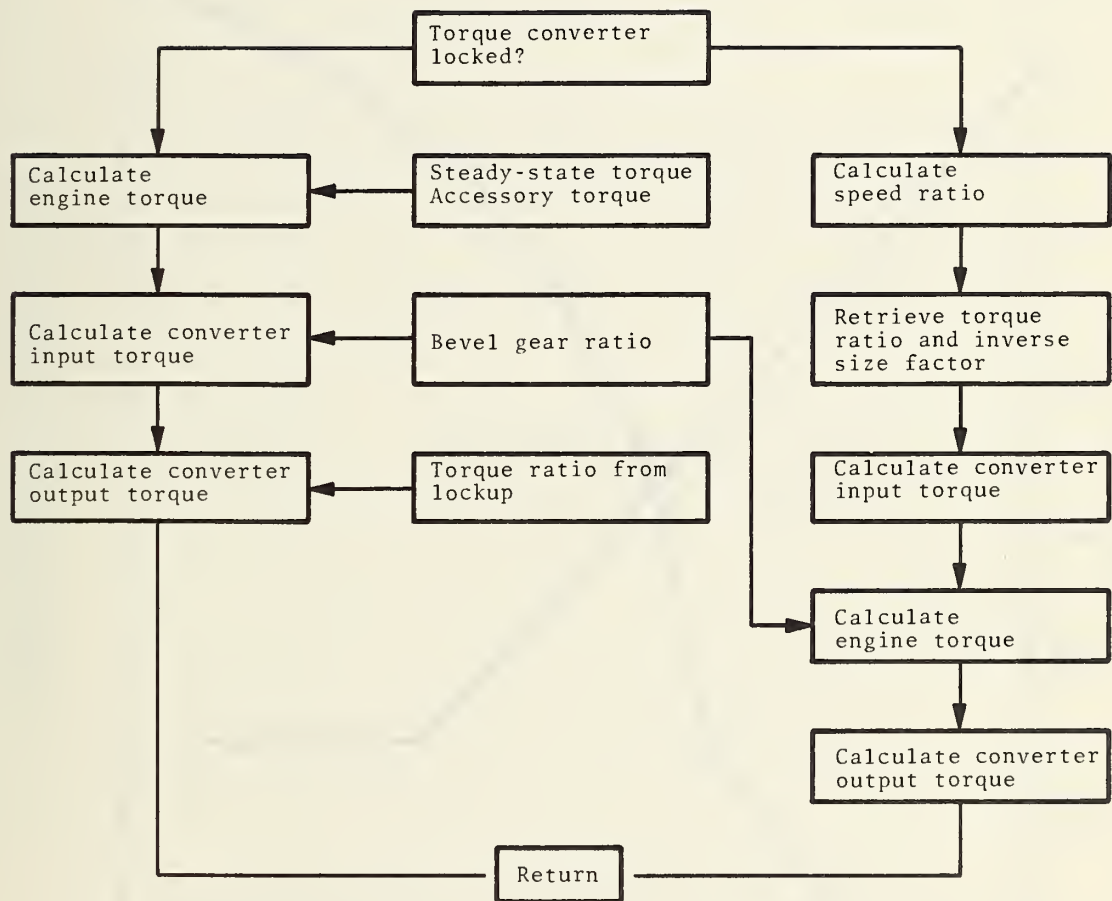


FIGURE 21. TQCONV FLOW DIAGRAM

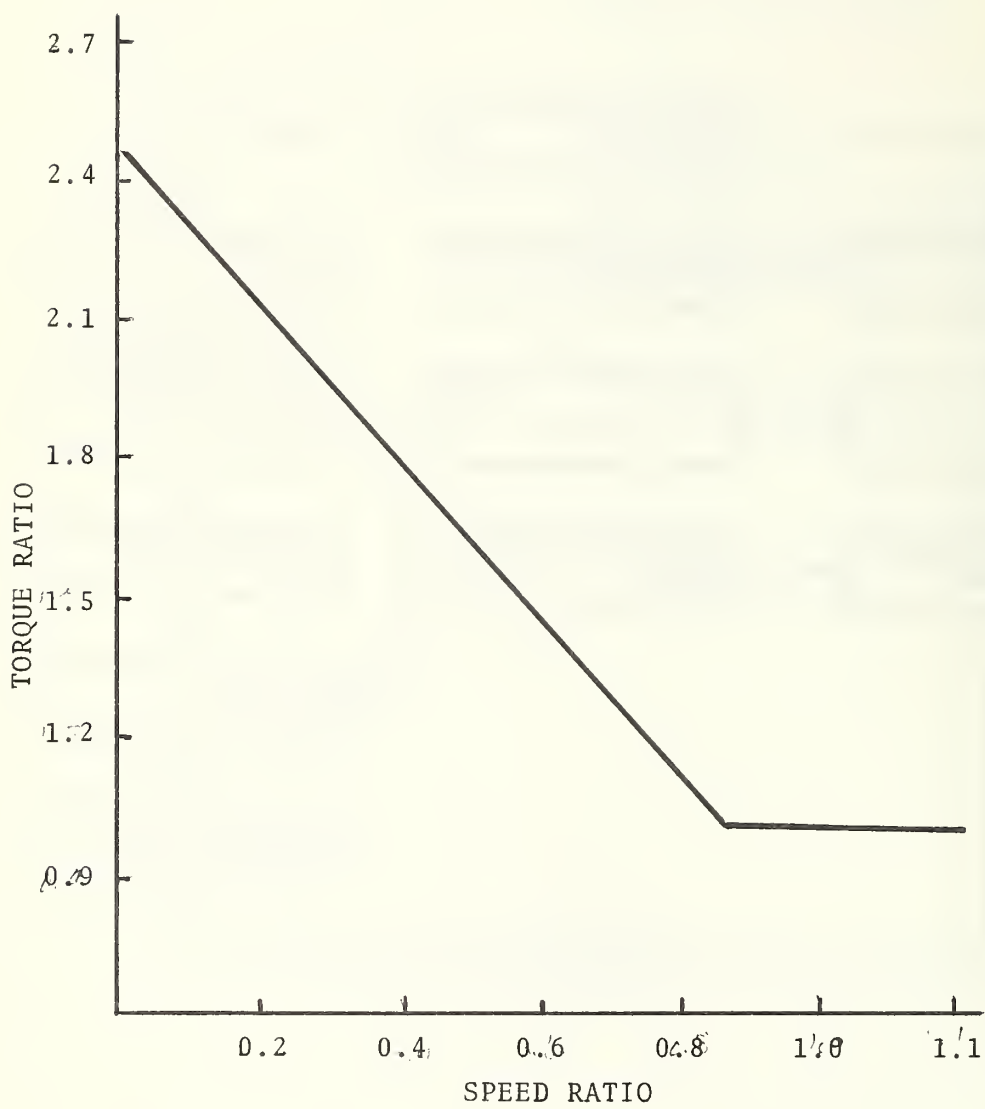


FIGURE 22. SPEED RATIO VS TORQUE RATIO

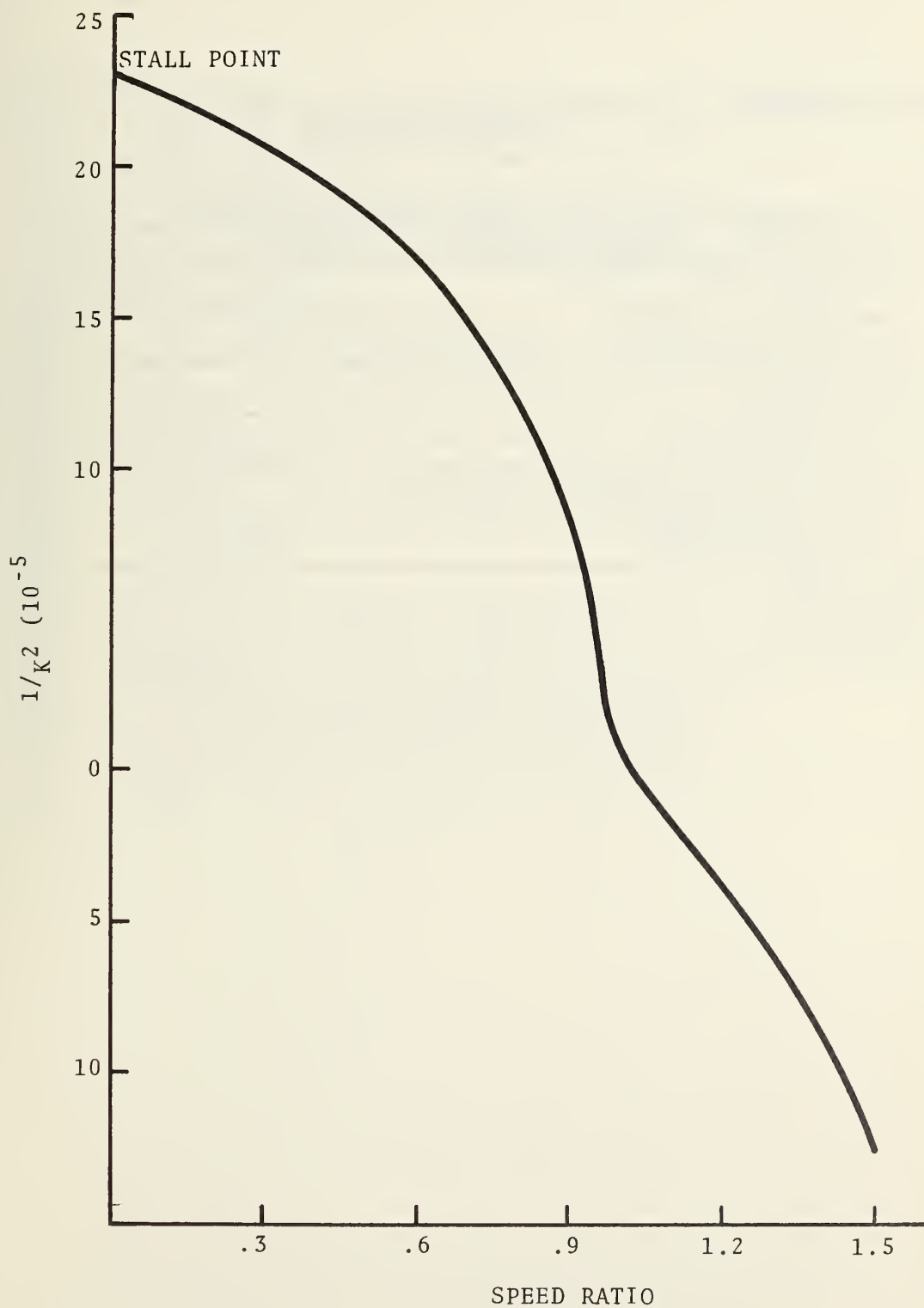


FIGURE 23. SPEED VS $1/K^2$

BUS SIMULATION PROGRAM

```

1: *                                     **** TCCONV ****
2:
3:
4:
5: SUBROUTINE TCCONV( LOCK,PA0C,SST0RG,ACT0RG,TA01TR,
6: C TAI1SR,TA0N,BA0N,BA0C,TA0C)
7: COMMON /BGEAR/ BGRTI0
8: IF (LOCK .GE. 1)
9: C PA0C=SST0RG-ACT0RG;
10: CBAC=PA0C*BGRTI0;
11: CTAC=BA0C*TA01TR ;
12: C G0T0 900
13: 10 CONTINUE
14: TAI1SR=TA0N/BA0N
15: CALL VELTERP(TAI1SR,TA01TR,TAI3IK)
16: BA0C=BA0N*BA0N*TAI3IK
17: PA0C=BA0C/BGRTI0
18: TA0C=BA0C*TA01TR
19: 900 CONTINUE
20: 999 CONTINUE
21: RETURN
22: END

```

US SIMULATION PROGRAM

DATE

```
1: * **** VELTERP ****
2: SUBROUTINE VELTERP(SR,TR,RBK)
3: DIMENSION AAY(20,3)
4: COMMON /TGC/AAY
5: C***** FIRST COLUMN HOLDS THE SPEED RATIO
6: C***** IT IS CHAINED THROUGH TO FIND INTERPOLATION POINTS
7: C***** THE SECOND COLUMN HOLDS THE TORQUE RATIOS
8: C***** THE THIRD COLUMN HOLDS THE INVERSE SIZE FACTOR
9: C***** SR SPEED RATIO
10: C***** TR TORQUE RATIO
11: C***** RBK INVERSE SIZE FACTOR
12: IF (SR .GT. AAY(20,1)) GOTO 5
13: IF (SR .LT. AAY(1,1)) GOTO 10
14: I=0
15: GOTO 20
16: 5 CONTINUE
17: TR=AAY(20,2)
18: RBK=AAY(20,3)
19: GOTO 30
20: 10 CONTINUE
21: TR=AAY(1,2)
22: RBK=AAY(1,3)
23: GOTO 30
24: 20 CONTINUE
25: I=I+1
26: IF (AAY(I+1,1).GT. SR ) GOTO 40
27: GOTO 20
28: 40 CONTINUE
29: DELTX=(SR -AAY(I,1))/(AAY(I+1,1)-AAY(I,1))
30: TR=AAY(I,2)+DELTIX*(AAY(I+1,2)-AAY(I,2))
31: RBK=AAY(I,3)+DELTIX*(AAY(I+1,3)-AAY(I,3))
32: 30 CONTINUE
33: RETURN
34: END
```

3.3.25 Transmission Gear Efficiency - TREFF

PROGRAM NAME: TREFF

TYPE OF SUBROUTINE: System Computation

DESCRIPTION: This subroutine calculates the transmission efficiency for the gear in which the bus is running as a function of driveshaft torque and speed.

MODELING: The transmission gear efficiency data are modeled by a two-dimensional polynomial least squares curve fit of the form:

$$\begin{aligned} \eta = & \eta_o + \frac{\partial \eta}{\partial T} \Delta T + \frac{\partial \eta}{\partial N} \Delta N + \frac{\partial^2 \eta}{\partial N^2} \Delta N^2 + \frac{\partial^2 \eta}{\partial T^2} \Delta T^2 \\ & + \frac{\partial^2 \eta}{\partial T \partial N} \Delta T \Delta N + \frac{\partial^3 \eta}{\partial N^3} \Delta N^3 + \frac{\partial^3 \eta}{\partial T^3} \Delta T^3 \\ & + \frac{\partial^3 \eta}{\partial N \partial T^2} \Delta N \Delta T^2 + \frac{\partial^3 \eta}{\partial N^2 \partial T} \Delta N^2 \Delta T \end{aligned}$$

where

η = Gear efficiency

η_o = Gear efficiency at a selected operating point

ΔN = Driveshaft speed variation about the selected operating point

ΔT = Driveshaft torque variation about the selected operating

The $\frac{\partial \eta}{\partial T}$ term is a measure of the change in efficiency with respect to torque at constant speed; $\frac{\partial \eta}{\partial N}$ is a measure of the change in efficiency with respect to speed at constant torque, etc. The $\frac{\partial^2 \eta}{\partial T \partial N}$ represents a measure of the change in efficiency with respect to the combined torque-speed surface. The number of terms in the equation could be extended for a closer fit. This fit uses nine terms.

The partial differential terms become the coefficients in the curve fit used to model gear efficiency as a function of driveshaft speed and torque. These coefficients

are selected by a least squares algorithm.

However, this curve is only used to fit the available data. Provisions must be made for cases when the range of the available data is exceeded. The data do not extend to zero torque or zero speed. Therefore reasonable extrapolations need to be made. The extrapolation to zero speed had already been made for the data used in this program for 1st and 2nd gear and these points were incorporated in the curve fit. Once the curve fits were made, efficiencies were calculated well beyond the upper and lower torque bounds of the data to determine how far the fits could reasonably be extended with respect to driveshaft torque. The curves in Figs. 24, 25 and 26 show the efficiencies as a function of driveshaft torque at constant speeds for 1st, 2nd and 3rd gear, respectively. These curves were used as an aid in determining how far the model could reasonably be extended. Further, plotting the curves by the computer gave a check of data and interpolation scheme of the program.

One of the problems in obtaining transmission gear efficiency in the simulation occurs because the data give efficiency as a function of driveshaft torque and speed. The speed is known but the torque is supplied from the engine side of the transmission and the driveshaft torque is unknown until the efficiency of the transmission is known. To circumvent this problem the driveshaft torque is estimated using the current torque into the transmission and the efficiency calculated in the previous iteration. In both the real time and digital simulations, the entire program iterates often enough that the change in efficiency is not large enough to warrant an iterative procedure to obtain efficiency.

The coefficients for the curve fit equation are read in for each gear and are stored in a matrix. In cases where more than three gears are used in the simulation, first

and last gear use the first and third gear efficiencies respectively and all the intermediate gears use the second gear efficiency model, since no efficiency data for more than three gears are presently available.

The data obtained for the transmission used in the simulation did not include efficiencies for low torques. Since efficiency is zero when the torque is zero some means of reflecting the efficiencies between this point and the lower boundary of the data needed to be employed. This is done by using an exponential interpolation (see Eqs. 3 and 4). However, in the transmission, as has been previously indicated, it is necessary to use the efficiency of the previous iteration to estimate the current driveshaft torque. If the efficiency is allowed to be zero, each succeeding iteration will result in zero driveshaft torque and the car won't move. For this reason the efficiency is interpolated between the curve fit boundary and a small arbitrary efficiency (0.05).

In cases where the torque exceeds the maximum torque allowed for the model the efficiency is just set to the value at the boundary. Since this happens very seldom the resulting error is not significant and the sole purpose is to prevent incongruities in the program when this does occur.

Shift criteria prevent 1st and 2nd gear from exceeding the speed boundaries and 3rd gear has its boundary set at 4000 RPM (about 115 mph for a 2.75 rear axle).

The curve fit equation (Statement 70 in the program) is organized so as to minimize the number of operations. The last statement of the program calculates driveshaft speed based on the new efficiency.

A flow diagram and a block diagram of the subroutine are given in Figs. 27 and 28.

EQUATIONS:

$$1) \quad T_{DS} = T_{CO} \cdot GR_{TR} \cdot \eta_{TR}$$

$$2) \quad \eta_{TR} = \eta_0 + C_1 \Delta T + C_2 \Delta N + C_3 \Delta T^2 + C_4 \Delta N^2 + C_5 \Delta T \Delta N + C_6 \Delta T^3 + C_7 \Delta N^3 + C_8 \Delta T \Delta N^2 + C_9 \Delta T^2 \Delta N$$

The efficiency interpolation equation for use below the valid region of curve fit is:

$$\eta_{TR} = 1. - .95 \exp(K \cdot T_{DS})$$

where

$$K = \frac{\ln((1. - \eta_{TR_L})/.95)}{T_{DS_L}}$$

INPUT VARIABLES:

<u>Variable Name</u>	<u>Symbol</u>	<u>Description</u>
T9IC	T_{DS}	Driveshaft torque
T9IN	N_{DS}	Driveshaft speed
TA0C	T_{CO}	Converter output torque
TB01GR	GR_{TR}	Transmission gear ratio
TB01EF	η_{TR}	Transmission gear efficiency (from previous iteration)
TB01GI	BI	Gear index

OUTPUT VARIABLES:

<u>Variable Name</u>	<u>Symbol</u>	<u>Description</u>
T9IC	T_{DS}	New driveshaft torque
TB01EF	η_{TR}	New transmission gear efficiency

VARIABLES WHICH MUST BE STORED IN MEMORY:

TBC1GI(J)	GI _j ; j = 1, 10	Indicates which gear to use for efficiency calculation. Has value 1, 2 or 3; 1 indicates low gear, 3 indicates high gear, 2 indicates intermediate gears.
-----------	-----------------------------	---

TBC1GI(I,ID) C_{i,id}; i = 1,10 Coefficients of curve
id = 1,4 fit equation.

OTHER PROGRAM VARIABLES:

I	i	Indicates use of first, second or third gear efficiency model.
ID	id	Indicates which of the four sets of coefficients to use in the curve fit (second gear uses two different sets).
T9DCMN	T_{DS_L}	Lowest torque for which curve fit is valid.
T9DCM	T_{DS_U}	Highest torque for which curve fit is valid.
DBD3T	ΔT_{DS}	Difference between the current driveshaft torque and the driveshaft torque at the curve fit operating point.
DBD3N	ΔN_{DS}	Difference between the current driveshaft speed and the driveshaft speed at the curve fit operating point.
INTERP	FLAG	A flag which is set to 1 if interpolation is required.

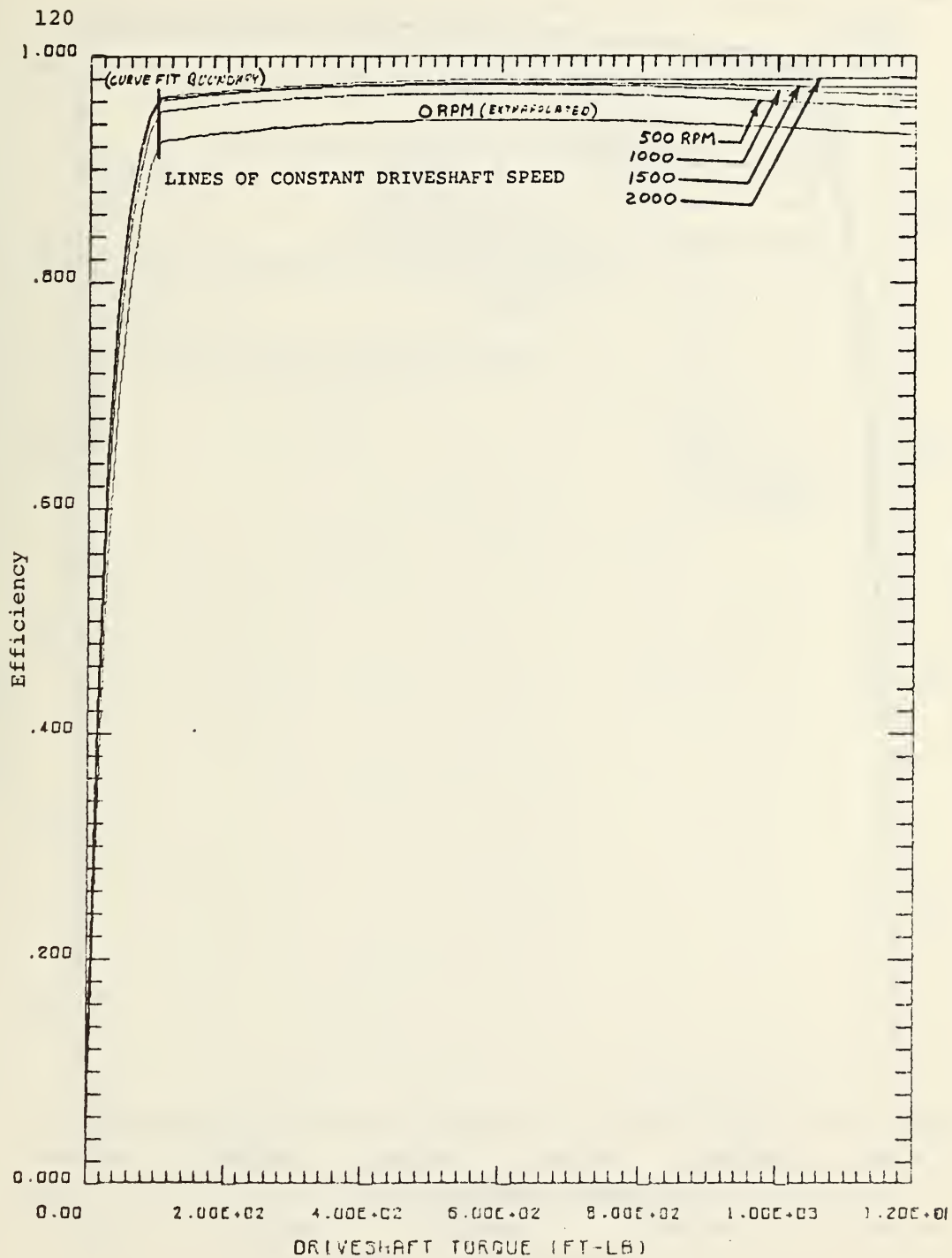


FIGURE 24. TRANSMISSION EFFICIENCY - FIRST GEAR

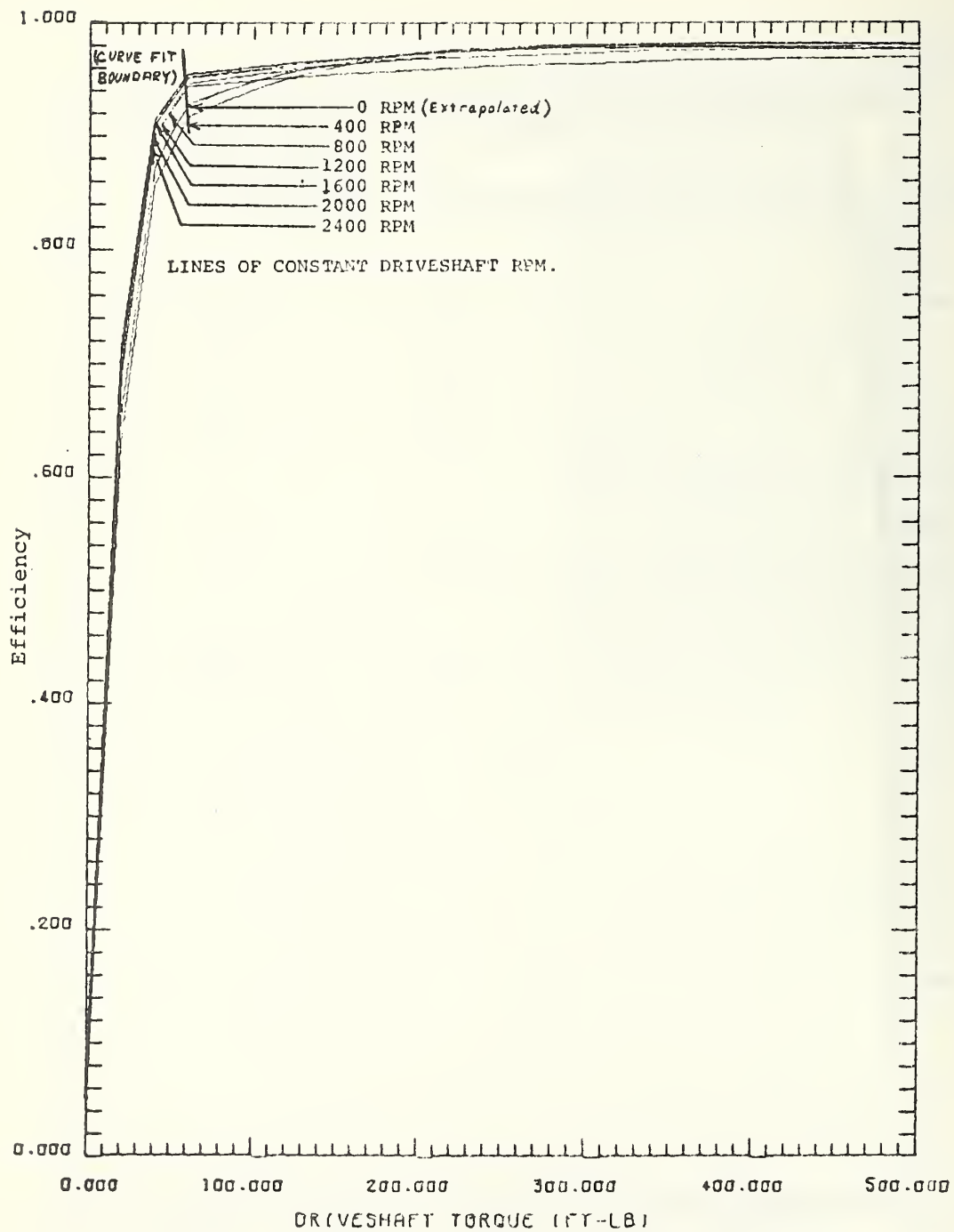


FIGURE 25. TRANSMISSION EFFICIENCY - SECOND GEAR

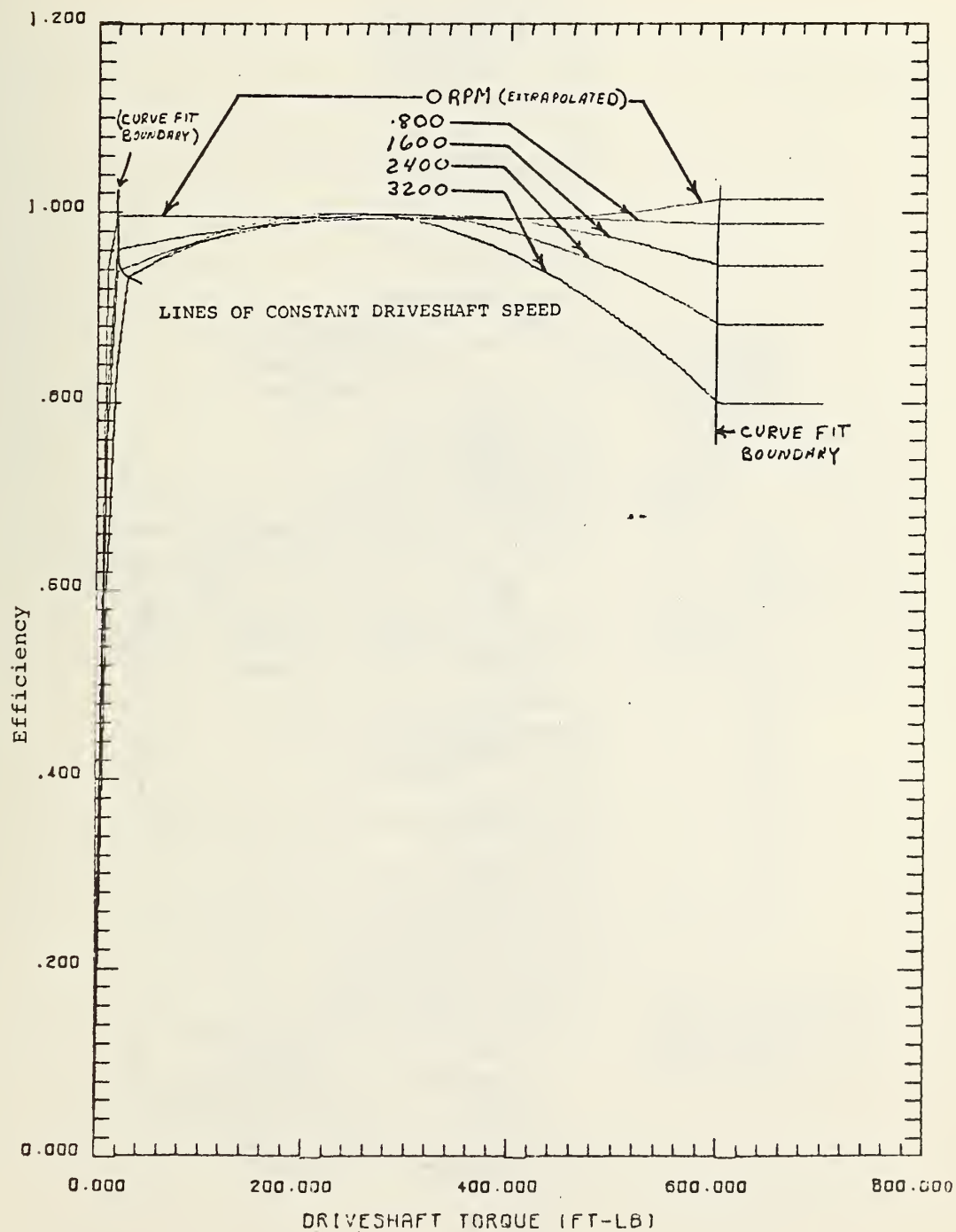


FIGURE 26. TRANSMISSION EFFICIENCY - THIRD GEAR

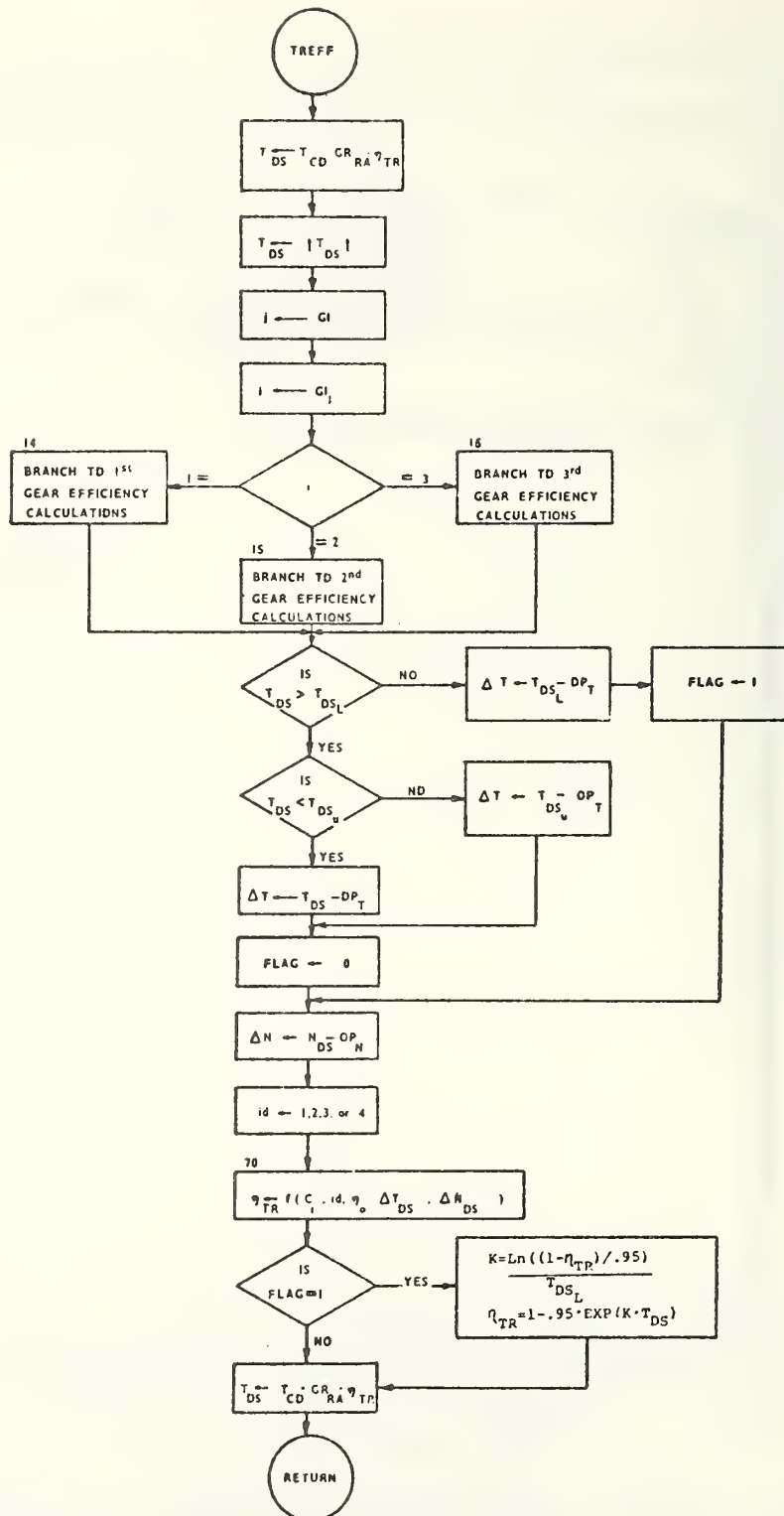


FIGURE 27. TRANSMISSION GEAR EFFICIENCY DIAGRAM

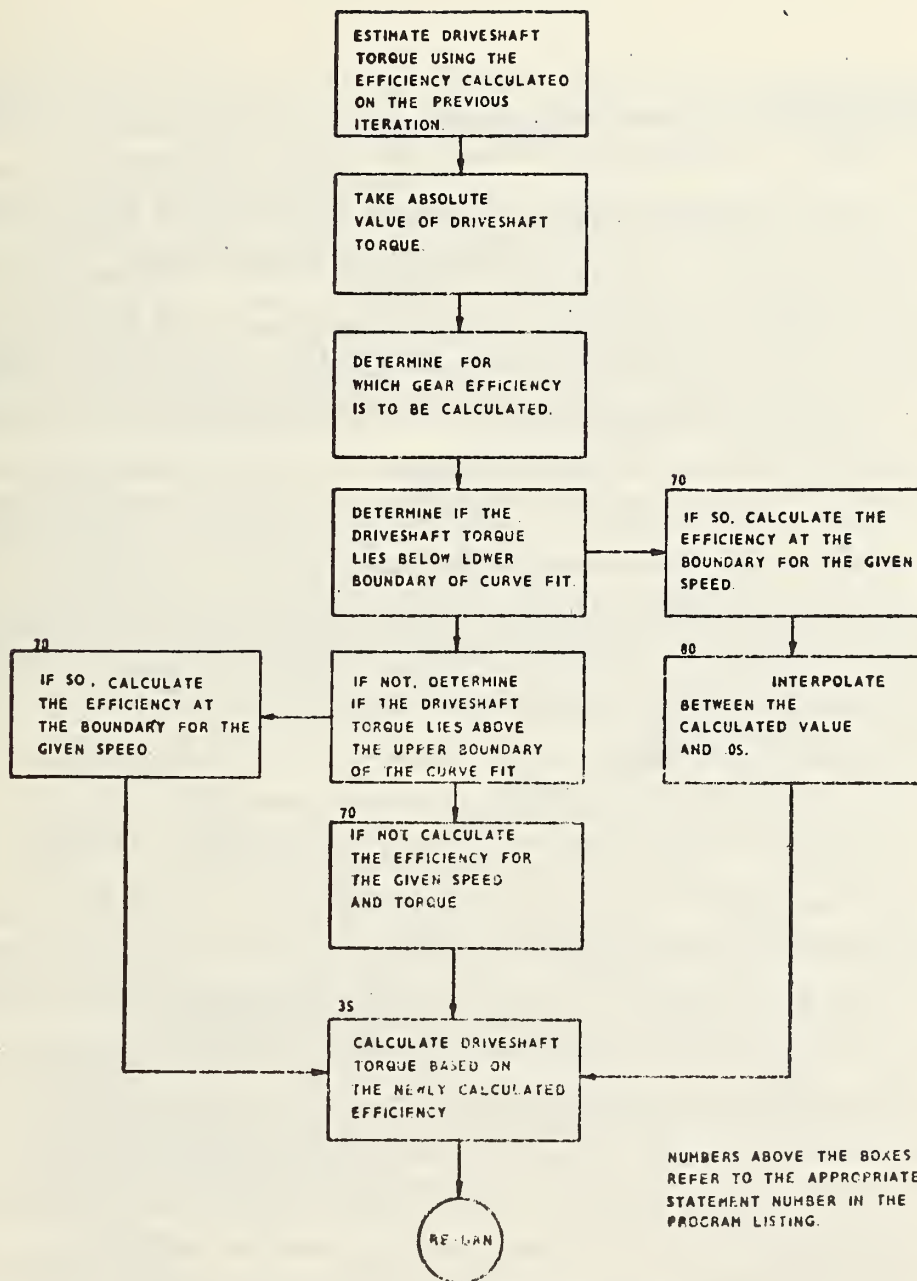


FIGURE 28. TRANSMISSION GEAR EFFICIENCY BLOCK DIAGRAM

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1: *                                     **** TREFF ****
2: C---- SUBROUTINE TO DETERMINE TRANSMISSION GEAR EFFICIENCY
3: C****
4: C--- AS A FUNCTION OF DRIVESHAFT TORQUE AND SPEED FOR THE GEAR IN WHICH
5: C---- DAN KAPellen 10/73, REVISED 2/12/74
6: C--- SUBROUTINE TREFF(TARC,TB01GR,TB01EF,TB01GI,T9IN,T9IC)
7: C--- C5948N /GEAREF/ TBC1GI(10,4),TBC1GI(10)
8: C---- THIS SUBROUTINE CALCULATES THE EFFICIENCY FOR A C-6 AUTOMATIC
9: C---- TRANSMISSION AS A FUNCTION OF DRIVESHAFT TORQUE AND SPEED BASED ON
10: C---- DATA SUPPLIED FOR EACH OF THE THREE GEARS. THE DATA IS MODELED
11: C---- WITH A THREE DIMENSIONAL CURVE FIT BASED ON A TAYLOR SERIES EXPANS
12: C---- THE VARIABLES USED IN THIS SUBROUTINE ARE AS FOLLOWS,
13: C---- T9IN=DRIVESHAFT SPEED (RPM)
14: C---- T9IC=DRIVESHAFT TORQUE (FT-LB)
15: C---- TB01EF=TRANSMISSION GEAR EFFICIENCY
16: C---- T9DCMN=MINIMUM DRIVESHAFT TORQUE FOR WHICH EFFICIENCY DATA WAS AVA
17: C---- T9DCMX=MAXIMUM DRIVESHAFT TORQUE FOR WHICH EFFICIENCY DATA WAS AVAI
18: C---- INTERP=A FLAG USED TO DETERMINE IF THE EFFICIENCY IS TO BE INTERPO
19: C---- TB03T1,2,3=DRIVESHAFT TORQUE OPERATORS USED IN THE CURVE FITS
20: C---- TB03N1,2,3=DRIVESHAFT SPEED OPERATORS USED IN THE CURVE FITS
21: C-----*****
22: C---- THIS SUBROUTINE CALCULATES THE TRANSMISSION GEAR EFFICIENCY AS A F
23: C---- CAR IS RUNNING. THE PROGRAM VARIABLES ARE AS FOLLOWS,
24: C---- INPUT VARIABLES-----
25: C---- BGRTIO--- THE BEVEL GEAR RATIO
26: C---- T9IC=DRIVESHAFT TORQUE
27: C---- T9IN=DRIVESHAFT SPEED
28: C---- TA9C=CONVERTOR OUTPUT TORQUE
29: C---- TB01GR=TRANSMISSION GEAR RATIO
30: C---- TB01EF=TRANSMISSION GEAR EFFICIENCY FROM PREVIOUS ITERATION.
31: C---- TB01GI=GEAR IN WHICH CAR IS BEING DRIVEN
32: C---- OUTPUT VARIABLES-----
33: C---- T9IC=DRIVESHAFT TORQUE AS CALCULATED BASED ON THE NEW EFFICIENCY
34: C---- TB01EF=NEW TRANSMISSION GEAR EFFICIENCY
35: C---- OTHER PROGRAM VARIABLES-----
36: C---- TBC1GI(J)-INDICATES WHICH GEAR TO USE FOR THE EFFICIENCY CALCULATI
37: C---- TBC1GI(I,ID)-COEFFICIENTS OF THE CURVE FIT EQUATIONS
38: C---- ID-INDICATES WHICH SET OF CURVE FIT COEFFICIENTS TO USE
39: C---- T9DCMN--LOWEST D.S. TORQUE FOR WHICH CURVE FIT IS CONSIDERED VALID
40: C---- T9DCMX--HIGHEST D.S. TORQUE FOR WHICH CURVE FIT IS CONSIDERED VALID.
41: C---- DBD3T--DEVIATION FROM CURVE FIT D.S. TORQUE OPERATING POINT.
42: C---- DBD3N--DEVIATION FROM CURVE FIT D.S. SPEED OPERATING POINT.
43: C---- INTERP-A FLAG WHICH IS SET TO 1 IF INTERPOLATION IS REQUIRED.
44: C-----*****
45: C---- ESTIMATE CURRENT DRIVESHAFT TORQUE BASED ON EFF. FROM PREVIOUS ITE
46: C---- T9IC=TA9C*TB01GR*TB01EF
47: C---- USE ABSOLUTE VALUE OF DRIVESHAFT TORQUE FOR EFFICIENCY CALCULATION
48: C---- T9IC=ABS(T9IC)
49: C---- DETERMINE WHICH GEAR EFFICIENCY IS TO BE CALCULATED.
50: C---- J=TB01GI
51: C---- I=TBC1GI(J)
52: C---- IF(I-2)14,15,16
53: C-----*****

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54: C-----FIRST GEAR EFFICIENCY-----
55: C-----
56: C---- DETERMINE IF THE DRIVESHAFT TORQUE FALLS BELOW LOWER BOUNDARY OF CURV
57: 14 T9DCMN=100.
58: IF (T9IC-T9DCMN)22,31,23
59: C---- IF SO CALCULATE THE EFFICIENCY AT THE BOUNDARY.
60: 22 DBD3T =T9DCMN -500.
61: C-----SET THE INTERPOLATION FLAG TO 1.
62: INTERP=1
63: G9 TO 10
64: C---- DETERMINE IF THE D.S. TORQUE LIES BEYOND THE UPPER BOUNDARY OF CURV
65: 23 T9DCM=1600.
66: IF (T9IC-T9DCM)31,31,24
67: C---- IF SO CALCULATE THE EFFICIENCY AT THE UPPER BOUNDARY.
68: 24 DBD3T =T9DCM-500.
69: G9 TO 25
70: 31 DBD3T =T9IC-500.
71: 25 INTERP=0
72: 10 DBD3N =T9IN-600.
73: ID=1
74: G9 TO 70
75: C-----
76: C-----SECOND GEAR EFFICIENCY-----
77: C-----SECOND GEAR USES TWO SETS OF CURVE FIT EQUATI
78: C-----
79: 15 CONTINUE
80: IF (T9IN-2400.)44,40,40
81: C---- DETERMINE IF THE DRIVESHAFT TORQUE FALLS BELOW LOWER BOUNDARY OF CU
82: 40 T9DCMN=50.
83: IF (T9IC-T9DCMN)41,34,42
84: 41 DBD3T =T9DCMN-175.
85: ID=3
86: C-----SET THE INTERPOLATION FLAG TO 1.
87: INTERP=1
88: G9 TO 11
89: C---- DETERMINE IF THE D.S. TORQUE LIES BEYOND THE UPPER BOUNDARY OF CURV
90: 42 T9DCM=500.
91: IF (T9IC-T9DCM)34,34,43
92: C---- IF SO CALCULATE THE EFFICIENCY AT THE UPPER BOUNDARY.
93: 43 DBD3T =T9DCM-175.
94: ID=3
95: G9 TO 50
96: C---- REPEAT PROCESS FOR DRIVESHAFT SPEEDS LESS THAN 2400 RPM.
97: 44 T9DCMN=50.
98: IF (T9IC-T9DCMN)46,36,47
99: 46 DBD3T =T9DCMN-400.
100: ID=2
101: INTERP=1
102: G9 TO 11
103: 47 T9DCM=900.
104: 48 IF (T9IC-T9DCM)36,36,49
105: 49 DBD3T =T9DCM-400.
106: ID=2

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107:      GS TO 50
108:      36 DBD3T = T9IC-400.
109:      ID=2
110:      GS TO 11
111:      34 DBD3T = T9IC-175.
112:      ID=3
113:      50 INTERP=0
114:      11 DBD3N = T9IN-2400.
115:      GS TO 70
116: C*****
117: C*****THIRD GEAR EFFICIENCY*****
118: C*****
119:      16 CONTINUE
120:      IF (T9IN-2000.)66,60,60
121: C---- DETERMINE IF THE DRIVESHAFT TORQUE FALLS BELOW LOWER BOUNDARY OF
122:      60 T9DCMN=30.
123:      61 IF (T9IC-T9DCMN)62,33,63
124:      62 DBD3T =T9DCMN-275.
125: C----SET THE INTERPOLATION FLAG TO 1.
126:      INTERP=1
127:      GS TO 12
128: C---- DETERMINE IF THE D.S. TORQUE LIES BEYOND THE UPPER BOUNDARY OF C
129:      63 T9DCM=600.
130:      IF (T9IC-T9DCM)33,33,65
131: C---- IF SO CALCULATE THE EFFICIENCY AT THE UPPER BOUNDARY.
132:      65 DBD3T =T9DCM-275.
133:      GS TO 67
134: C---- REPEAT PROCESS FOR DRIVESHAFT SPEEDS LESS THAN 2000 RPM.
135:      66 T9DCMN=20.
136:      IF (T9IC-T9DCMN)62,33,63
137:      33 DBD3T = T9IC-275.
138:      67 INTERP=0
139:      12 DBD3N = T9IN-2000.
140:      ID=4
141:      70 CONTINUE
142: C---- CALCULATE THE EFFICIENCY FOR THE DESIRED D.S. SPEED AND TORQUE.
143:      TB91EF=TBC1GI(1,ID)+DBD3T*(TBC1GI(2,ID)+DBD3N*(TBC1GI(6,ID)
144:      1+DBD3N*TBC1GI(9,ID))+DBD3T*(TBC1GI(4,ID)+DBD3N*TBC1GI(10,ID)
145:      2+DBD3T*TBC1GI(7,ID)))+DBD3N*(TBC1GI(3,ID)+DBD3N*(TBC1GI(5,ID)
146:      3+DBD3N*TBC1GI(8,ID)))
147: C---- CHECK INTERPOLATION FLAG.
148:      IF (INTERP)35,35,80
149:      80 CONTINUE
150: C---- IF .GT. ZERO INTERPOLATE BETWEEN THE CALCULATED BOUNDARY EFFICIEN
151:      IF (1.00-TB91EF)81,82,82
152:      81 CONTINUE
153:      TB91EF=1.00
154:      82 CONTINUE
155: C---- THIS INTERPOLATION USES AN EXPONENTIAL, FIRST CALCULATE THE CONS
156: C---- USED IN THE EXPONENTIAL BASED ON THE TORQUE AND EFF AT THE CURVE
157:      SK=ALOG((1.-TB91EF)/.95)/T9DCMN
158: C---- THEN CALCULATE THE INTERPOLATED EFFICIENCY.
159:      TB91EF=1.-.95*EXP(SK*T9IC)

```

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160: C---- CALCULATE THE NEW D.S. TORQUE BASED ON THE NEWLY CALCULATED EFF  
161: 35 CONTINUE  
162:  
163: IF (TB01EF .GT. 1.0) TB01EF= .998  
164: T9IC=TAPC*TB81GR*TB01EF  
165: RETURN  
166: END
```

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3.3.26 Vehicle Dynamics Subroutine - VEDYN

PROGRAM NAME: VEDYN

TYPE OF SUBROUTINE: System Computation

DESCRIPTION: This subroutine determines the vehicle acceleration based on the difference between the force driving the vehicle and the resistive forces. It also tests for conditions of tire spinning or skidding.

MODELING: The road load power requirement is the most important part of this subroutine. It is defined as the force that must be provided by the engine to propel a vehicle at a constant speed. This force acts on the wheels at the tireroad interface of the drive sheels. As can be seen in the block diagram of Fig. 29, there are two options for determining road load as a function of vehicle speed: 1) by use of the road load equation, and 2) by linearly interpolating between steady state driveshaft torques in speed increments of 10 mph. The first option allows the user to specify and vary frontal area, drag coefficient, tire rolling friction, grade angle, and mass independently. The second option allows the user to store the total road load torque required at the driveshaft at speed increments of 10 mph. The latter is useful when road load torque data are obtained experimentally at the driveshaft for a specific vehicle and a curve fit is not desired.

The braking force is determined from a brake constant and a brake setting. The brake constant is set equal to the vehicle

mass in the initialization program (INICON). The brake setting varies between 0 and 1. This means that if the tires did not slip the resultant deceleration at full brake would be slightly more than 1 g, since road load adds to the brake force.

The net tractive force available to accelerate the vehicle is determined by computing the difference between the force applied to the tire-road interface by the engine and the resistive vehicle forces (Eq. 3).

Dividing the net tractive force by the inertial mass of the vehicle determines the resultant acceleration (Eq. 6).

However, the vehicle acceleration is limited by the coefficient of friction between the tires and road surface. The magnitude of the acceleration or deceleration is tested against the maximum and minimum possible as determined by the coefficient of static friction. If the maximum or minimum value is exceeded, the acceleration is set to the acceleration attained with the tires spinning or the deceleration with the tires skidding. (See note at end of "variables which must be stored in memory".)

Negative velocities are prevented by comparing the vehicle speed to $A\Delta t$ where Δt is the time step and A is the acceleration. Whenever the velocity would become negative within the next time step if calculated in

the normal manner the acceleration is set equal to the current velocity (see statements 56 and 59 in the listing.) This works well in the all-digital version, but in the real time simulations where the time steps vary between iterations, a larger time step is assumed than would ever be expected to occur. A flow diagram of the subroutine is given in Fig. 30.

It is also worthy to note that this program is presented in its most flexible form. The user can tailor it to decrease computation time and core space. If a user is sure no conditions for wheelslip will be encountered, this part of the program could be eliminated as well as grade angle and wind velocity if not needed, so that one of the options could be omitted. The rotational inertia of the drive train can also be approximated by a constant.

EQUATIONS:

$$1) \quad F_D = \frac{C_D A_F (V + V_W)^2}{2gc} \cdot \frac{5280^2}{3600} + \mu M(1 + C_G V) + M \cdot \sin \phi$$

F_D = Total drag

$$2) \quad R = F_D + B_S K_B$$

R = Total vehicle resistive force including brakes

$$3) \quad F_A + T_{RA}/R_T - R$$

F_A = Net acceleration force available

$$4) \quad J = ((J_{CT} + J_{TR}) \cdot GR_{TR}^2 + J_{RA}) \cdot GR_{RA}^2 + J_{TW}$$

J - Effective inertia at the rear wheels

$$5) \quad M_I = M + J/R_T^2$$

M_I = Equivalent mass of the vehicles

$$6) \quad A = \frac{F_A \cdot g_c}{M_I}$$

A = Acceleration of vehicle

$$7) \quad A = A_{\text{MINS}} \cdot g \quad \text{if} \quad A/g \leq -A_{\text{MIN}}$$

$$8) \quad A = A_{\text{MAXS}} \cdot g \quad \text{if} \quad A/g \geq A_{\text{MAX}}$$

A_{MINS} = maximum deceleration (see note on next page)

A_{MAXS} = maximum acceleration

INPUT VARIABLES:

<u>Variable Name</u>	<u>Symbol</u>	<u>Description</u>
VVOS	V	Vehicle speed (mph)
T9OC	T_{RA}	Rear axle output torque (ft-lb)
VVIBBR or BS	B_S	Brake setting
TB01GR	GR_{TR}	Transmission gear ratio
T9I1GR	GR_{RA}	Equivalent rear axle ratio
TB01GI	GI	Gear index
AVI0	ϕ	Wind speed (mph)

OUTPUT VARIABLES:

VVOA	A	Vehicle acceleration
VVDF	F_D	Road load force

VARIABLES WHICH MUST BE STORED IN MEMORY:

VVIM	M	Vehicle mass (lb)
VVILFT	A_F	Frontal area (ft ²)
VVI1CD	C_D	Drag coefficient
VVI1RF	μ	Coefficient of rolling friction
TVIJRA	J_{RA}	Rear axle gear inertia (lbm-ft ²)
TVIJCT	J_{CT}	Torque converter turbine inertia (lbm-ft ²)
TVIJTR	J_{TR}	Transmission gear inertia (3rd gear)
TVICRL	T_i	Table of road load torques

LOADEQ	FLAG	Used to determine the method of calculating road load
VVIFUM	f_M	Coefficient of static tire friction (g's)
VVIFUS	f_s	Coefficient of slipping tire friction (g's)
VVIMAX	A_{MAX}	Maximum vehicle acceleration (g's)
VVIAS	A_{MAXS}	Maximum vehicle acceleration with wheel spin (g's)
VVI2BR	K_B	Brake constant

NOTE: This program assumes all four wheels to brake. Therefore the coefficient of static and slipping tire friction are also the maximum (A_{MIN}) and skidding (A_{MINS}) decelerations respectively. The maximum (A_{MAX}) and slipping (A_{MAXS}) acceleration are calculated in the initialization program (INICON) taking into account weight transfer and assuming the power wheels to be at the rear of the vehicle.

OTHER PROGRAM VARIABLES:

<u>Variable Name</u>	<u>Symbol</u>	<u>Description</u>
SINAVO	$SIN(\phi)$	Sine approximation for grade angle
TVIMJ	J	Rotary inertia of drive train as seen at the rear wheels
VVDFBR	R	Total vehicle resistive force including brakes (lb)
VVDFN	F_A	Net force available at the pavement to accelerate the vehicle (lb)
VVDMI	M_I	Inertial mass of vehicle (g's)
WHLSLP		Used in real time simulation to control the noise generator for indicating tire slipping conditions to the driver.

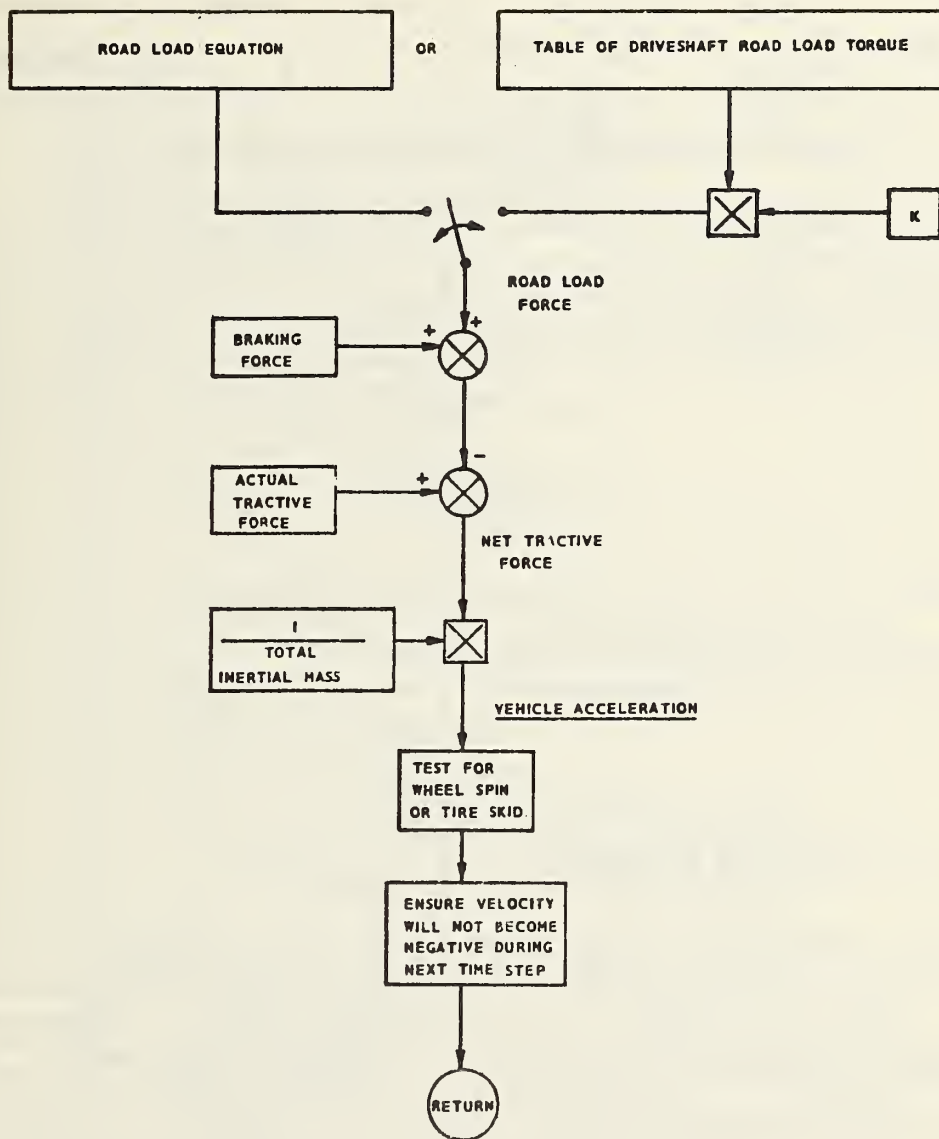


FIGURE 29. VEHICLE DYNAMICS BLOCK DIAGRAM

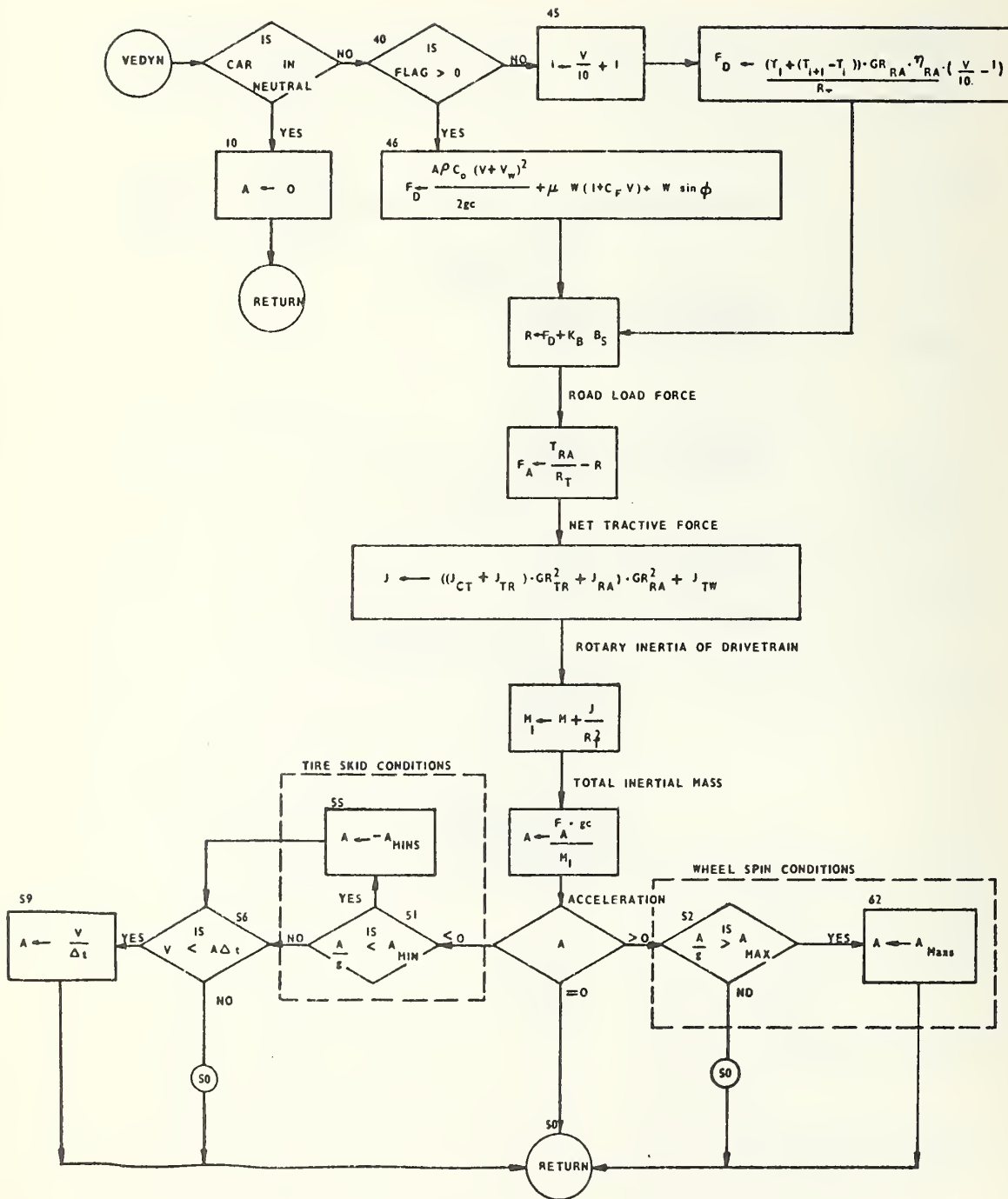


FIGURE 30. VEHICLE DYNAMICS FLOW DIAGRAM

VEHICLE SIMULATION PROGRAM

DATE

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1: *                                     *** VEDYN ***
2: SUBROUTINE VEDYN( TB01GI,VV0S,BS,T99C,TB01GR,T911GR,VV0A
3: C ,VVDF,T911,VVDFBR,VVDMI,DELTAT,VV0AO,
4: C TVIMJ)
5: C---- SUBROUTINE TO SIMULATE VEHICLE ACCELERATION AND BRAKING DYNAMICS
6: C---- DAN KAPFLEN 10/73
7: C-----*****
8: C---- THIS SUBROUTINE DETERMINES THE VEHICLE ACCELERATION BASED ON THE
9: C---- DIFFERENCE BETWEEN THE FORCE DRIVING THE VEHICLE AND THE RESISTIVE
10: C---- FORCES. IT ALSO TESTS FOR CONDITIONS OF TIRE SPINNING OR SKIDDING.
11: C---- INPUT VARIABLES-----
12: C---- VV0S- VEHICLE SPEED (MPH).
13: C---- T99C-REAR AXLE OUTPUT TORQUE (FT-LB).
14: C---- BS-BRAKE SETTING (0 TO 1)
15: C---- TB01GR-TRANSMISSION GEAR RATIO.
16: C---- T911GR-EQUIVALENT REAR AXLE RATIO.
17: C---- TB01GI-GEAR IN WHICH CAR IS OPERATING.
18: C---- AVIS-WIND SPEED (MPH)
19: C---- GRADE ANGLE (RAD)
20: C---- OUTPUT VARIABLES-----
21: C---- VV0A-VEHICLE ACCELERATION (MPH/SEC)
22: C---- VVDF-VEHICLE ROAD LOAD FORCE AT TIRE ROAD INTERFACE (LB).
23: C---- WHEELSP- USED IN R. T. SIMULATION TO CONTROL TIRE SLIP NOISE GENERAT
24: C---- PROGRAM CONSTANTS-----
25: C---- VVIM-VEHICLE MASS (LB).
26: C---- VVILFR-FRONTAL AREA (SQ. FT.).
27: C---- VVI1CD-DRAG COEFFICIENT.
28: C---- VVI1RF-COEFFICIENT OF ROLLING FRICTION.
29: C---- VVIFUM-COEFFICIENT OF STATIC TIRE FRICTION (G'S).
30: C---- VVIFUS-COEFFICIENT OF SLIPPING TIRE FRICTION (G'S).
31: C---- VVIMAX-MAX VEHICLE ACCEL (G'S). CALCULATED IN 'INICON'.
32: C---- VVIAS-MAX VEHICLE ACCEL WITH WHEEL SPIN(G'S). CALC. IN 'INICON'.
33: C---- VVI2BR-BRAKE CONSTANT. (LB).
34: C---- TVI,TVIJCT
35: C---- TVIJCT,TVIJTR,TVIJRA,TVIJTW- POLAR MOMENT OF INERTIA OF TORQUE
36: C---- CONVERTER TURBINE, TRANSMISSION, REAR AXLE, AND REAR WHEELS
37: C---- RESPECTIVELY(LBM-FT**2).
38: C---- LGADEQ-A USED IN A LOGICAL MANNER TO TO DETERMINE WHETHER
39: C---- LGADEQ- USED TO DETERMINE IF ROAD LOAD EQUATION IS OF TABLE IS USED.
40: C---- OTHER PROGRAM VARIABLES-----
41: C---- SINAV9-SINE APPROXIMATION FOR GRADE ANGLE.
42: C---- TVIMJ-TOTAL ROTARY INERTIA OF DRIVETRAIN REFLECTED TO REAR WHEELS.
43: C---- VVDFBR- TOTAL RESISTIVE FORCE ACTING ON VEHICLE INCLUDING BRAKES.
44: C---- VVDFN-NET FORCE AVAILABLE TO ACCELERATE VEHICLE.
45: C---- VVDMI-TOTAL INERTIAL MASS OF VEHICLE (G'S).
46: C-----*****
47: COMMON /AIR/ AVIS,AVIR,AVI0,AVIS,AVIM
48: COMMON /PMOMENT/ TVIJCT,TVIJTR,TVIJRA ,TVIJTW
49: COMMON /PRNT/ IBUT,IPRT,LGADEQ,MAXLIN
50: COMMON /MASS/ VVILFR,VVI1CD,VVI1RF,VVIMI,VVI2BR,VVIM,VVIMDR,
51: C VVISWB,VVISH,VVIAMX,VVIAS
52: COMMON /ROLD/ TVICRL(16)
53: COMMON /TIRE/ VVIDRR,VVIFUM,VVIFUS,VVI1CF

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IS SIMULATION PROGRAM

DATE 25

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54: *
55: C---- APPROXIMATE GRADE ANGLE TO AVOID USE OF SINE FUNCTION.
56: SINAVB=AVIB*(1.-AVI2*AVIB/6.)
57: WLSLP=C.
58: C---- IF CAR IS NOT IN GEAR SET ACCELERATION TO ZERO AND RETURN.
59: IF (TB01GI-.5) 10,10,40
60: 10 VVBA=C.
61: RETURN
62: 40 CONTINUE
63: C---- IF LOADED IS 1, USE ROAD LOAD EQUATION. IF ZERO USE D.S. TORQUE TABL
64: IF (LOADED) 45,45,46
65: 45 I=VVBS/10.+1.
66: VVDF=(TVICRL(I)+(TVICRL(I+1)-TVICRL(I))*(VVBS/10.-I))*T9I1GR+T9I1/
67: 1VVIDRR
68: GB TO 47
69: 46 CONTINUE
70: CVVIRF=.005+VVIRF*VVBS**2. *.00000C01
71: VVDF=.0334294*VVI1CD*VVILFR*AVIM*((VVSS+AVIS)**2)+
72: CVVIM*(.005+3.59*(VVBS*22./15.))**2. *10.**(-7))
73: C +SINAVB*VVIM
74: 47 CONTINUE
75: C---- ADD RESISTIVE FORCE TO BRAKING FORCE TO OBTAIN TOTAL RESISTIVE FORCE:
76: VVDFBR=VVDF+VVI2BR*BS
77: C---- OBTAIN NET FORCE AVAILABLE TO ACCELERATE THE VEHICLE.
78: VVDFN=T9UC/VVIDRR-VVDFBR
79: C---- CALCULATE TO TOTAL ROTARY INERTIA OF THE DRIVETRAIN AS SEEN AT THE
80: TVIMJ=(TVIJCT+TVIJTR)*((TB01GR+T9I1GR)**2)+TVIJRA*(T9I1GR**2)
81: 2+TVIJTW
82: C---- REAR WHEELS.
83: C---- DETERMINE THE INERTIAL MASS OF THE VEHICLE.
84: VVDMI=(VVIM+(TVIMJ/(VVIDRR**2)))/32.1739
85: C---- DETERMINE VEHICLE ACCELERATION.
86: VVBA=VVDFN/VVDMI
87: C*****
88: C---- DETERMINE IF THERE ARE ANY CONSTRAINTS ON THE CALCULATED ACCELERATION
89: C*****
90: IF (VVBA) 51,50,52
91: C---- IF ACCEL IS NEGATIVE CHECK IF TIRES ARE SKIDDING.
92: 51 IF (VVBA/32.1739+VVIFUM) 55,56,56
93: 55 CONTINUE
94: WLSLP=-1.
95: C---- IF TIRES ARE SKIDDING SET DECEL TO THAT OCCURRING UNDER SLIDING CONDIT
96: VVBA=-VVIFUG*32.1739
97: 56 CONTINUE
98: C---- ENSURE VELOCITY WILL NOT BECOME NEGATIVE DURING NEXT TIME STEP.
99: DELTAT=.01
100: IF (VVBS+VVBA*DELTAT*.681818) 59,59,50
101: 59 VVBA=-VVBS*1.46667/DELTAT
102: RETURN
103: C---- FOR POSITIVE ACCEL DETERMINE IF WHEELS ARE SPINNING.
104: 52 IF (VVBA-VVIAMX*32.1739) 50,50,62
105: 62 CONTINUE
106: WLSLP=-1.

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BUS SIMULATION PROGRAM

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107: C---- IF WHEELS ARE SPINNING SET ACCEL TO MAX POSSIBLE UNDER SLIP.
108:      VV0A=VV1AS*32.1739
109:      50 CONTINUE
110:      ABVV0A=ABS      (VV0A)
111:      IF(ABVV0A .LE. .01) VV0A=.0
112: C---- CHANGE VEHICLE ACCELERATION FROM FT/SEC/SEC TO MPH/SEC.
113:      VV0A=VV0A*.681818
114:      IF (VV0A .LE. 0 .AND. VV0S .LT. .1) VV0S=VV0A=VV0A0=0
115:      RETURN
116:      END

```

3.3.27 Subroutine to Interpolate Torque Ratio and Inverse
Size Factor - VELTERP

SUBROUTINE NAME: VELTERP

DESCRIPTION: SEE TQCONV

3.4 INPUT FORMATS

Data is entered into the system by the subroutines INICON, MAPER and RDEPA. AGNCON can be used to revise data and vary parameters when doing a series of runs. The following is a description of the input form.

<u>VARIABLE</u>	<u>INPUT FORMAT</u>	<u>MEANING</u>
COMM	13A6/13A6	Comment for heading
VVIMI	8E10.3	Inertial mass of bus
VVI2BR		Brake constant
VVIM		Vehicle mass
VVIMDR		Mass on drive wheels
RIE	8E10.3	Engine inertia
TMAX		Maximum engine torque
SCALEF	8E10.3	Engine size scale factor
TIDLE		Throttle idle setting
PIDLMIN		Minimum engine speed
PIDLMAX		Maximum engine speed
ACLOAD	8E10.3	Accessory load torque
VMIN(1)	8E10.3	Maximum value for joint prob.
PMAX(1)		Minimum value for joint prob. den.
VINT(1)		Interval size for joint prob. den.
VMIN(2)	8E10.3	(same as above except for second variable)
PMAX(2)		
CINT(2)		
NGEAR	I5	Number of transmission gears
TBC1GI	E11.5	Polynomial coefficients for calculating gear efficiencies
ITC1GI	I1	Index for assigning gear efficiency calculations
TBC1GR	8E10.3	Gear ratios for transmission
BGRATIO	F10.6	Bevel gear ratio
GR1	8E10.3	Gear ratio for first gear
TVIJCT		Polar moment of converter
TVIJTR		Polar moment of transmission
TBDTMS		Length of shift
TBDTH		Time between shifts

<u>VARIABLE</u>	<u>INPUT FORMAT</u>	<u>MEANING</u>
T8I1GR	8E10.3	Rear axle ratio
TVIJRA		Polar moment of rear axle
VVIDRR	8E10.3	Tire rolling radius
VVIFUM		Coefficient of maximum tire friction
VVIFUS		Sliding coefficient of tire friction
VVI1CF		Tire coulomb friction coefficient
TVIJTW		Polar moment of tires and wheels
T8INV	F6.1	Corrected driveshaft speed
VVILFR	8E10.3	Frontal area
VVI1CD		Drag coefficient
VVI1RF		Rolling friction coefficient
VVISWB	8E10.3	Wheel base
VVISH		Height of vehicle center of gravity
FUELWT		Fuel weight
AVIB	8E10.3	Air pressure
AVIR		Air temperature
GAIN		Gain for vedyn
DELMIN		Autodr minimum lead time
IOUT	K10	DT's between printouts
IPRNT		Print control
LOADEQ		Road load calculator switch
TVICRL	F5.1	Roadload
DT	F10.6	Time increment
AVIO	8E10.3	Grade angle
AVIS		Wind speed
GRMAX(I)	4F10.5	Maximum driveshaft speed for Gear I
GRMAXCR(I)	8F10.5	Maximum driveshaft speed while cruising
GRMIN(I)	F10.5	Minimum driveshaft speed for Gear I
AWAY	2F10.5,F10.8	Converter Gear Ratio and size factor
SRNEW	8F10.5	Speed ratio during lockup
TRNEW		Torque ratio during lockup
SROLD		Speed ratio when unlocking
TROLD		Speed ratio when unlocking
TIMLOCK		Length of lockup

<u>VARIABLE</u>	<u>INPUT FORMAT</u>	<u>MEANING</u>
ACCLOCK	8F10.5	Lockup velocity at wide open throttle
DECLOCK		Unlock velocity
ACCRUIS	8F10.5	Lockup velocity for cruising mode
<u>MAPER</u>		
F(50,9)	5x,9F7.2	Array to hold torque and fuel maps
MAP1(1,I)	9I7	First line of MAP1
MAP3(1,I)	9I7	First line of MAP3
<u>RDEPA</u>		
ACEL	3F8.3,I8,F8.3	Acceleration rate
VCRUIS		Cruise speed
DECFL		Deceleration rate
NSTOP		Number of stops
RTLNGT		Route length
TDWELL		Time spent at dwell
<u>SIMULA</u>		
ISTOP	I2	End of computer run flag

3.5 SAMPLE DATA DECK

This section reproduces a sample data deck.

*DATA	2.5 MPHDC	**THIS SIMULATION**				25 MPH	
	TORQUE CONVERTER TC490	24350 LB.			TRANSMISSION V730		
24350.	24350.	24350.	12175.				
27.54	1040.0	25.8	1.0	0.030	900.0	2200.	
22.	24.4	26.3	29.	34.4	42.	51.8	64.3
64.2	64.2	64.2					
250.	750.	50.					
500.	2400.	100.					
2							
.07100E+00	.31533E-05	.19142E-04	.61697E-07	.35170E-07			
.24961E-08	.42920E-10	.22369E-10	.11561E-10	.19293E-10			
.07600E+00	.11786E-04	.78043E-05	.28614E-06	.78379E-09			
.46761E-08	.15687E-09	.22690E-11	.37415E-11	.83041E-10			
.06470E+00	.18473E-03	.11159E-05	.12043E-05	.50000E-08			
.10200E-05	.23667E-08	.80999E-12	.13525E-09	.65877E-09			
.09850E+00	.14185E-04	.27977E-05	.81397E-06	.15365E-08			
.42516E-07	.38182E-09	.62692E-12	.31066E-10	.46935E-09			
122							
2.0667	1.40	1.000					
.875							
2.0667	2.50	3.50	10.0	15.0			
5.143	4.5						
1.708	.0	.65	.01	40.52			
.	420.	840.	1260.	1680.	2100.	2520.	2980.
75.	.7	.008					
295.6	48.	7.21					
14.1747	60.	0.03	.1				
	20	-1	1				
.05							
.020.	1580.	9999.					
.000.	1580.	9999.					
.0000.	550.	1520.					
.00000	2.45995	.000231207					
.10000	2.33982	.000228655					
.20000	2.16999	.000221179					
.30000	1.98506	.000206864					
.40000	1.80236	.000194834					
.45000	1.70567	.000189145					
.50000	1.61217	.000183530					
.55000	1.52337	.000178040					
.60000	1.44011	.000171737					
.70000	1.27716	.000157817					
.75000	1.12261	.000148809					
.80000	1.10623	.000138023					
.83000	1.05307	.000129790					
.86200	.99755	.000116967					
.91230	.99811	.000081106					
.92460	.99829	.000071215					
.92480	.99829	.000071035					
1.0	.098	.0.0					
1.25	.098	-.000045					
1.50	.098	-.000130					

1.0	.06	.6	1.2	.5					
28.0	8.6								
22.5									
800.									
800	-144.4	0.0	144.4	263.0	360.6	475.8	520.4	682.8	728.
800	11.	11.	11.	17.17	24.2	28.27	30.64	40.56	52.8
800	0.0	.5	1.5	2.5	3.5	4.5	5.5	31.2	81.
1000.									
1000	-107.	0.0	107.	215.	302.8	404.4	408.9	593.5	732.
1000	16.	16.	16.	21.6	27.5	32.6	40.14	47.58	58.8
1000	0.0	1.0	2.0	3.0	5.0	6.0	33.0	38.	81.
1200.									
1200	-130.	0.0	130.	260.0	354.5	460.06	542.7	637.3	721.1
1200	19.	19.	19.	25.64	32.64	39.5	47.	55.4	66.33
1200	0.0	5.7	11.4	17.87	24.35	30.8	37.29	43.77	81.
1400.									
1400	-130.	0.0	130.	258.	352.6	446.4	544.0	637.7	731.5
1400	22.	22.	22.	30.291	37.98	44.05	54.81	63.7	74.88
1400	0.0	6.6	13.2	20.74	28.28	35.8	43.35	50.91	81.
1600.									
1600	-170.	0.0	170.7	261.0	351.2	443.8	535.0	626.2	717.2
1600	26.	26.	26.	39.4	45.48	52.02	61.29	71.34	83.25
1600	0.0	7.8	15.6	23.9	32.25	40.50	48.9	57.24	81.
1800.									
1800	-198.	0.0	198.4	281.	364.7	447.9	531.0	612.7	697.3
1800	34.	34.	34.	42.42	50.63	59.4	68.8	78.75	90.58
1800	0.0	10.2	20.4	29.0	37.5	46.1	54.6	59.5	81.
2000.									
2000	-217.	0.0	217.9	293.6	360.5	445.1	520.7	596.1	672.2
2000	42.	42.	42.	49.9	58.0	66.6	75.0	85.8	97.5
2000	0.0	12.45	24.9	33.54	42.2	50.85	59.5	68.16	81.
2200.									
2200	-230.	0.0	236.	304.6	373.1	442.6	512.3	582.5	651.7
2200	50.	50.	50.	57.4	65.4	73.8	83.	92.85	104.4
2200	0.0	15.5	30.9	39.24	47.6	55.95	64.20	72.66	81.
2200									
800	2200	7	0	100	50	1	100	0	
800	2200	7	-50	050	10	1	100	0	
2.5	25.	2.5		5	1.0	16.			

REFERENCES

1. Beachley, N.H. and Frank, A. A., "Digital Automotive Propulsion Simulator Programs and Description," Vol. II, Department of Electrical and Computer Engineering, University of Wisconsin - Madison, Contract No. DOT-OS-30112, Dec. 1974.
2. "TRANS BUS Procurement Requirements - Part II: Technical Specifications," Booz-Allen Applied Research, Draft Report for Department of Transportation - UMTA, Washington DC, December 1975.
3. "Small Bus," RRC International, Inc., Preliminary Draft Report 5, DOT-UT-30015, UMTA, Date Unknown.
4. Letter Communication from GMC, Detroit Allison Division, 1975.
5. "California Steam Bus Project Technical Evaluation," R. A. Renner IRT - REPT - 301 - R, Jan. 1973.
6. Letter Communication AiResearch Mfg. Company, 1975.

APPENDIX A
Plot Program

TYPE OF SUBROUTINE: Output

DESCRIPTION: This program takes the output from
OUTVAR and plots it on a Calcomp
plotter.

MODELING: This program inputs from a tape with a
maximum of twenty-five channels each of
which holds values of a variable outputted
by OUTVAR. Channel 1 holds the x axis
values which is usually time. Six plots
can be done using the same x axis. The
program will then ask if more plots are
wanted so up to 24 plots can be made
from the same tape. Following is a com-
plete listing of the plot program and a
sample plot.

The Calcomp subroutines used are de-
scribed in (3).

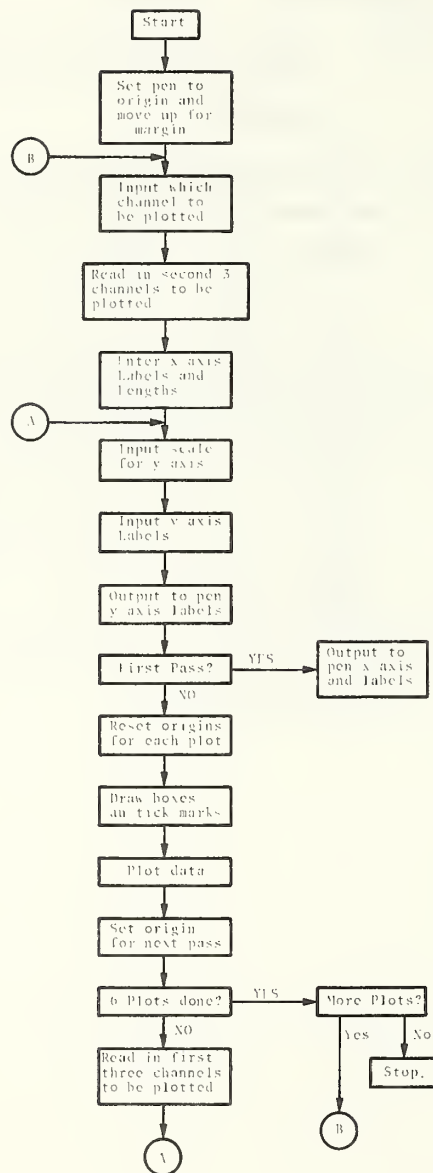


FIGURE A-1 FLOW DIAGRAM FOR PLOT PROGRAM

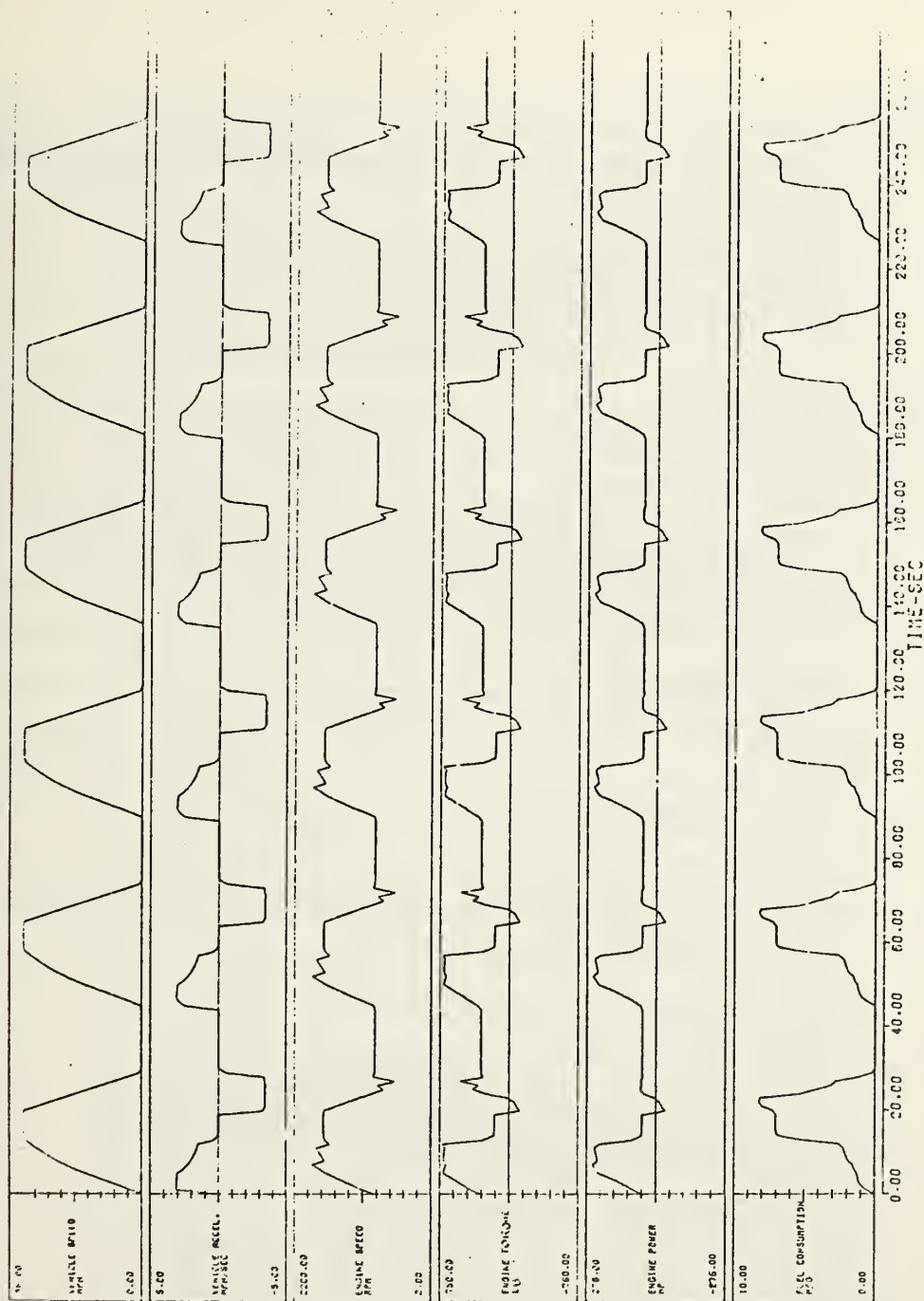


FIGURE A-2. GRAPHIC DISPLAY OF TYPICAL OUTPUT DATA

FORTRAN LS,B9

```

1: *.
2:   DIMENSION B(25),ARRAY1(1500),ARRAY2(1500),ARRAY3(1500),X(1500)
3:   REAL MAX(3),MIN(3)
4:   REAL PMAX
5:   DIMENSION INPUT(10),RINPUT(5)
6:   EQUIVALENCE (INPUT(1),RINPUT(1))
7:   DIMENSION NC(3,2),NCH(6)
8:   EQUIVALENCE (NCH(1),NC(1,1))
9:   DIMENSION C1(6),C2(6),C3(6),C4(6)
10: *.
11: 1001 FORMAT(10I)
12: 1002 FORMAT(10(1,/,))
13: 1003 FORMAT(10A8)
14: 1030 FORMAT(' CHANNEL',14,2X,'MAXIMUM IS',F10.3,2X,'MINIMUM IS',F10.3)
15: 1031 FORMAT(F10.3)
16: 1032 FORMAT(' MAX =',F10.3)
17: 1040 FORMAT(' ENTER Y AXIS LABELS FOR EACH CHANNEL WHEN ASKED.',/,/,
18:   ' TWO (2) LINES ARE REQUIRED EACH UP TO 16 CHARACTERS',/,/,
19:   ' PROGRAM WILL ECHO YOUR ENTRY. IF YOU DONT LIKE IT,/,/,
20:   ' PRESS SS2 AND CLEAR PAUSE TO REENTER BOTH LINES')
21: 1041 FORMAT(' ENTER 2 LINES FOR CHANNEL',14)
22: 1042 FORMAT(' NUMBER OF POINTS IS ',15)
23: *.
24:   CALL PLOTS(0,0,16)
25: C ** MOVE ORIGIN UP 0.6 INCHES TO START
26:   CALL PLOT(0,0,0.6,-3)
27:   1 CONTINUE
28:   NPASS = 1
29: *.
30: C ** CHANNEL SELECTION
31: C **
32:   50 DO 51 K=1,10
33:     51 INPUT(K) = 0
34:     OUTPUT(102) ' ENTER CHANNELS TO BE PLOTTED -- EX. 9,2,4,7,3,5'
35:     READ(101,1001) INPUT
36: C ** DETERMINE NUMBER OF CHANNELS
37:   NCHANS = 0
38:   DO 55 K=1,10
39:     IF(INPUT(K).EQ.0) GO TO 60
40:     NCHANS = NCHANS + 1
41:   55 CONTINUE
42:   60 IF(NCHANS.GT.6) OUTPUT(102) ' TO MANY CHANNELS -- FIRST 6 USED'
43:   OUTPUT(102) ' YOU HAVE SELECTED THE FOLLOWING CHANNELS'
44:   OUTPUT(102) ' TO CHANGE -- PRESS SS2'
45:   WRITE(102,1002)(INPUT(K),K=1,6)
46:   PAUSE 02
47:   IF(SENSE SWITCH 2) 50,70
48:   70 DO 72 J=1,2
49:     DO 71 I=1,3
50:       NC(I,J) = INPUT(I+3*(J-1))
51:   71 CONTINUE
52:   72 CONTINUE

```

```

53: C ** ENTER AXIS LABELS
54:   WRITE(101,1040)
55:   DO 84 K=1,6
56:     DO 81 J=1,10
57:       81 INPUT(J) = 4H
58:       82 WRITE(101,1041) NCH(K)
59:       READ(101,1003) (RINPUT(J),J=1,2)
60:       READ(101,1003) (RINPUT(J),J=3,4)
61:       OUTPUT(102) ' YOUR ENTRY WAS '
62:       WRITE(102,1003) (RINPUT(J),J=1,2)
63:       WRITE(102,1003) (RINPUT(J),J=3,4)
64:       PAUSE 02
65:       IF (SENSE SWITCH 2) 82,83
66:       83 C1(K) = RINPUT(1)
67:         C2(K) = RINPUT(2)
68:         C3(K) = RINPUT(3)
69:         C4(K) = RINPUT(4)
70:       84 CONTINUE
71: C **
72: C ** PLOT SECTION -- PLOTS CHANNELS IN REVERSE ORDER
73: C **
74:   DO 700 NPASS = 1,2
75: C ** SET UP NEW BRIGIN IF SECOND PASS
76:   IF (NPASS.EQ.2) CALL PLOT(-1.0,1.8,-3)
77:   MPASS = 2
78:   IF (NPASS.EQ.2) MPASS = 1
79:   100 NT = 0
80: C ** CLEAR ARRAYS
81:   DO 105 K=1,1500
82:     ARRAY1(K) = 0.0
83:     ARRAY2(K) = 0.0
84:     ARRAY3(K) = 0.0
85:     X(K) = 0.0
86:   105 CONTINUE
87: C ** READ TAPE AND LOAD ARRAYS
88:   REWIND 100
89:   CALL EOFSET(1503)
90:   110 READ(100) B
91:   NT = NT+1
92:   X(NT) = B(1)
93:   ARRAY1(NT) = B(2,MPASS)
94:   ARRAY2(NT) = B(3,MPASS)
95:   ARRAY3(NT) = B(4,MPASS)
96:   IF (NT.LT.1498) GO TO 110
97:   OUTPUT(102) ' MORE THAN 1498 PRINTS IN FILE '
98:   GO TO 160
99: C ** EOF SECTION
100: 150 OUTPUT(102) ' EOF ENCOUNTERED '
101: 160 WRITE(102,1042) NT
102:   IF (NPASS.EQ.2) GO TO 200
103: C ** ENTER X AXIS LENGTH
104:   OUTPUT(102) ' ENTER X AXIS LENGTH IN INCHES -- F10.3 '
105:   READ(101,1031) AXLEN
106:   OUTPUT(102) ' ENTER X AXIS LABEL -- 1A8 '

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107:      READ(101,1003) DX
108: C ** DETERMINE MAX AND MIN
109:      DO 210 K=1,3
110:          MAX(K) = -999999.0
111:          MIN(K) = 999999.0
112:      210 CONTINUE
113:      DO 220 K=1,NT
114:          IF (ARRAY1(K).GT.MAX(1)) MAX(1)=ARRAY1(K)
115:          IF (ARRAY1(K).LT.MIN(1)) MIN(1)=ARRAY1(K)
116:          IF (ARRAY2(K).GT.MAX(2)) MAX(2)=ARRAY2(K)
117:          IF (ARRAY2(K).LT.MIN(2)) MIN(2)=ARRAY2(K)
118:          IF (ARRAY3(K).GT.MAX(3)) MAX(3)=ARRAY3(K)
119:          IF (ARRAY3(K).LT.MIN(3)) MIN(3)=ARRAY3(K)
120:      220 CONTINUE
121:      OUTPUT(102) ' ENTER DESIRED MAXIMUMS FOR Y AXIS'
122:      OUTPUT(102) '   USE POS. NUMBER FOR PLOT FROM 0 TO MAX'
123:      OUTPUT(102) '   USE NEG. NUMBER FOR PLOT FROM -MAX TO +MAX'
124:      OUTPUT(102) ' IF YOU MAKE A MISTAKE, PRESS SS2 AND CLEAR PAUSE'
125:      DO 230 K=1,3
126:          MMAX = MAX(K)
127:      230 WRITE(102,1030) NC(K,MPASS),MMAX ,MIN(K)
128:      OUTPUT(102) ' ENTER DESIRED MAXIMUM -- F10.3'
129:      READ (102,1031) MAX(K)
130:      WRITE(102,1032) MAX(K)
131:      PAUSE 02
132:      IF (SENSE SWITCH 2) 225,230
133:      230 CONTINUE
134: C ** SET FIRST VALUE AND SCALE FACTOR
135:      IF (MAX(1).GT.0.0) ARRAY1(NT)=0.0
136:      IF (MAX(1).GT.0.0) ARRAY1(NT+1)=MAX(1)/1.6
137:      IF (MAX(1).LE.0.0) ARRAY1(NT)=MAX(1)/0.8
138:      IF (MAX(1).LE.0.0) ARRAY1(NT+1)=-MAX(1)/0.8
139:      IF (MAX(2).GT.0.0) ARRAY2(NT)=0.0
140:      IF (MAX(2).GT.0.0) ARRAY2(NT+1)=MAX(2)/1.6
141:      IF (MAX(2).LE.0.0) ARRAY2(NT)=MAX(2)/0.8
142:      IF (MAX(2).LE.0.0) ARRAY2(NT+1)=-MAX(2)/0.8
143:      IF (MAX(3).GT.0.0) ARRAY3(NT)=0.0
144:      IF (MAX(3).GT.0.0) ARRAY3(NT+1)=MAX(3)/1.6
145:      IF (MAX(3).LE.0.0) ARRAY3(NT)=MAX(3)/0.8
146:      IF (MAX(3).LE.0.0) ARRAY3(NT+1)=-MAX(3)/0.8
147:      X(NT)=0.0
148:      TT = X(NT-1)/AXLEN
149:      IT = X(NT-1)/AXLEN
150:      IF (TT.GT.IT) TT=IT+1.0
151:      X(NT+1)=TT
152:      ZERO=0.0
153:      NPLTS = 3
154:      DO 602 N = 1,NPLTS
155: C **
156: C   Y1 IS YAXIS FOR LOWER SCALE NUMBER
157: C   Y2 IS YAXIS FOR 2ND LINE OF YAXIS LABEL
158: C   Y3 IS YAXIS FOR 1ST LINE OF YAXIS LABEL
159: C   Y4 IS YAXIS FOR 16F SCALE NUMBER
160: C **

```

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161:      Y1=0.2+(N-1)*1.7
162:      Y2=Y1+0.6
163:      Y3=Y1+0.7
164:      Y4=Y1+1.35
165:      M=4-N
166:      L = M
167:      IF(NPASS.EQ.1) L=7-N
168: C ** WRITE Y AXIS LABELS
169:      IF(MAX(M).GT.0.0) CALL NUMBER(--2,Y1,0.07,ZERO,0.0,2)
170:      IF(MAX(M).LE.0.0) CALL NUMBER(--2,Y1,0.07,MAX(M),0.0,2)
171:      CALL SYMBOL(--2,Y2,.07,C3(L),0.0,8)
172:      CALL SYMBOL(999.,999.,.07,C4(L),0.0,8)
173:      CALL SYMBOL(--2,Y3,.07,C1(L),0.0,8)
174:      CALL SYMBOL(999.,999.,.07,C2(L),0.0,8)
175:      IF(MAX(M).GT.0.0) CALL NUMBER(--2,Y4,.07,MAX(M),0.0,2)
176:      IF(MAX(M).LE.0.0) CALL NUMBER(--2,Y4,.07,-MAX(M),0.0,2)
177:      602 CONTINUE
178:      610 CALL PLOT(1.0,0.0,-3)
179:      IF(NPASS.EQ.2) GO TO 620
180: C ** DRAW X AXIS IF FIRST PASS
181:      CALL AXIS(0.0,0.0,DX,-3,AXLEN,0.0,0.0,TT)
182:      620 D9 600 N=1,3
183: C ** SET NEW ORIGIN AT LOWER LEFT SF PLOT FOR EACH CHANNEL
184:      IF(N.EQ.1) CALL PLOT(0.0,0.1,-3)
185:      IF(N.E.1) CALL PLOT(0.0,1.7,-3)
186: C ** DRAW BOX AROUND TITLE
187:      CALL PLOT(-1.3,0.0,2)
188:      CALL PLOT(-1.3,1.6,2)
189:      CALL PLOT(0.0,1.6,2)
190:      CALL PLOT(0.0,0.0,2)
191: C ** DRAW Y AXIS TICK MARKS
192:      D9 601 NN=1,9,1
193:      PN=NN*0.160
194:      IF(NN.NE.5) CALL PLOT(-0.05,PN,3)
195:      IF(NN.EQ.5) CALL PLOT(-0.10,PN,3)
196:      CALL PLOT(0.05,PN,2)
197:      601 CONTINUE
198: C ** DRAW BOX AROUND PLOT
199:      CALL PLOT(0.0,0.0,3)
200:      CALL PLOT(AXLEN,0.0,2)
201:      CALL PLOT(AXLEN,1.60,2)
202:      CALL PLOT(AXLEN,0.8,3)
203:      M = 4-N
204: C ** DRAW CENTERLINE IF NECESSARY
205:      IF(MAX(M).LE.0.0) CALL PLOT(0.0,0.8,2)
206:      CALL PLOT(0.0,1.6,3)
207:      CALL PLOT(AXLEN,1.6,2)
208:      600 CONTINUE
209:      NTENT=1
210:      IF(MAX(S).GT.0.0) CALL PLOT(0.0,-3.4,-3)
211:      IF(MAX(S).LE.0.0) CALL PLOT(0.0,-3.6,-3)
212:      CALL LINE(X,APRAY3,NT,1,0.0)
213:      IF(MAX(P).GT.0.0) CALL PLOT(0.0,-0.2,-3)
214:      IF(MAX(2).GT.0.0) CALL PLOT(0.0,1.9,-3)

```

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215: IF (MAX(2).LE.0.0) CALL PLOT(0.0,1.7,-3)
216: CALL LINE(X,ARRAY2,NT,1,0,0)
217: IF (MAX(2).GT.0.0) CALL PLOT(0.0,-0.2,-3)
218: IF (MAX(1).GT.0.0) CALL PLOT(0.0,1.9,-3)
219: IF (MAX(1).LE.0.0) CALL PLOT(0.0,1.7,-3)
220: CALL LINE(X,ARRAY1,NT,1,0,0)
221: IF (MAX(1).GT.0.0) CALL PLOT(0.0,-0.2,-3)
222: 700 CONTINUE
223: C ** SET UP ORIGIN FOR NEW PLOT
224: XNEW = AXLEN + 10.0
225: CALL PLOT(XNEW,-8.4,-3)
226: C ** MORE PLOTS
227: REWIND 100
228: OUTPUT(102) ' TYPE 1 IF YOU WANT MORE PLOTS'
229: READ(101,1001) INPUT(1)
230: IF (INPUT(1).EQ.1) GO TO 1
231: C ** OTHERWISE TERMINATE
232: CALL PLOT(0.0,0.0,999)
233: CALL EXIT
234: END

```

APPENDIX B

Bus Simulation Program Listing

```

BUS SIMULATION PROGRAM                                DATE 29 MAR 1977    PAGE    0002

      2.5 MPH'S      **BUS SIMULATION**      25 MPH
      TORQUE CONVERTER T6400      24352 LB.      TRANSMISSION V770
      24352.000 24352.000 24352.000 12175.000
      375E 02 .104E 04 .258E 02 .100E 01 .300E 01 .900E 03 .220E 04
      AC0000
      237E 02 .244E 02 .263E 02 .292E 02 .344E 02 .420E 02 .518E 02 .643E 02
      553E 02 .763E 02
      VMIN(1), ETC
      220E 03 .700E 03 .500E 02
      VMIN(2), ETC
      250E 03 .240E 04 .100E 03
      VGEAR
      3
      T6400(1,1)
      777E 02 .3300E-05 .1714E-04 .61697E-07 .52170E-07
      .2435E-03 .3937E-10 .2236E-10 .1156E-10 .19295E-10
      .777E 02 .1175E-04 .7443E-04 .2551E-06 .76379E-09
      .6764E-03 .16687E-05 .2249E-11 .37415E-11 .9304E-10
      .5577E 03 .14473E-03 .1111E-05 .12045E-05 .5000E-08
      .1000E-06 .25647E-03 .4579E-12 .13025E-09 .65677E-09
      .5500E 03 .14473E-03 .1777E-05 .1577E-05 .1738E-08
      .5504E-07 .3312E-09 .5259E-12 .1006E-10 .46935E-09
      T6400
      2230000000
      5134101
      207E 01 .140E 01 .100E 01
      LEVEL GEAR RATIO STATION
      678000
      371, ETC
      207E 01 .250E 01 .350E 01 .100E 02 .150E 02
      T6400, ETC
      514E 01 .750E 01
      V1200, ETC
      171E 01 .800E 00 .650E 00 .100E 01 .400E 02
      T6400
      0 20.0 40.0 120.0 160.0 210.0 250.0 290.0 330.0 380.0 420.0 460.0
      V1200=V1200, V1200
      700E 02 .700E 00 .400E 02
      V1200, ETC
      226E 03 .420E 02 .700E 01
      V1200, ETC
      140E 02 .600E 02 .300E 01 .100E 00
      T6400, ETC
      20      -1      1
      V1200
      0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
      51
      65000
      V1200 .000000000
      V1200 .000000000
      51
      22.000001587.000009999.00000
      51
  
```

BUS SIMULATION PROGRAM									
480.00001580.00000000.0000									
DATE 29 MAR 1977 PAGE 0003									
9399.00000 550.000001820.00000									
ACCUISY TEST DATA									
SPEED RATIO*10000E RATIO*0.0E/4**2									
1.00000	2.45555	.00023121							
.10000	2.33889	.00022595							
.20000	2.18555	.00022117							
.30000	1.98889	.00020636							
.40000	1.70833	.00017453							
.50000	1.70867	.00016415							
.60000	1.61817	.00014351							
.70000	1.52237	.00012224							
.80000	1.44111	.00010174							
.90000	1.27716	.00008562							
1.00000	1.19751	.00007481							
1.10000	1.10663	.00006372							
1.20000	1.00537	.00005275							
1.30000	.99735	.00004697							
1.40000	.89711	.00003522							
1.50000	.89829	.00002712							
1.60000	.79829	.00001713							
1.70000	.69829	.00000713							
1.80000	.59829	.00000000							
1.90000	.49829	.00000000							
2.00000	.39829	.00000000							
2.10000	.29829	.00000000							
2.20000	.19829	.00000000							
2.30000	.09829	.00000000							
2.40000	.00000	.00000000							
2.50000	.00000	.00000000							
2.60000	.00000	.00000000							
2.70000	.00000	.00000000							
2.80000	.00000	.00000000							
2.90000	.00000	.00000000							
3.00000	.00000	.00000000							
3.10000	.00000	.00000000							
3.20000	.00000	.00000000							
3.30000	.00000	.00000000							
3.40000	.00000	.00000000							
3.50000	.00000	.00000000							
3.60000	.00000	.00000000							
3.70000	.00000	.00000000							
3.80000	.00000	.00000000							
3.90000	.00000	.00000000							
4.00000	.00000	.00000000							
4.10000	.00000	.00000000							
4.20000	.00000	.00000000							
4.30000	.00000	.00000000							
4.40000	.00000	.00000000							
4.50000	.00000	.00000000							
4.60000	.00000	.00000000							
4.70000	.00000	.00000000							
4.80000	.00000	.00000000							
4.90000	.00000	.00000000							
5.00000	.00000	.00000000							
5.10000	.00000	.00000000							
5.20000	.00000	.00000000							
5.30000	.00000	.00000000							
5.40000	.00000	.00000000							
5.50000	.00000	.00000000							
5.60000	.00000	.00000000							
5.70000	.00000	.00000000							
5.80000	.00000	.00000000							
5.90000	.00000	.00000000							
6.00000	.00000	.00000000							
6.10000	.00000	.00000000							
6.20000	.00000	.00000000							
6.30000	.00000	.00000000							
6.40000	.00000	.00000000							
6.50000	.00000	.00000000							
6.60000	.00000	.00000000							
6.70000	.00000	.00000000							
6.80000	.00000	.00000000							
6.90000	.00000	.00000000							
7.00000	.00000	.00000000							
7.10000	.00000	.00000000							
7.20000	.00000	.00000000							
7.30000	.00000	.00000000							
7.40000	.00000	.00000000							
7.50000	.00000	.00000000							
7.60000	.00000	.00000000							
7.70000	.00000	.00000000							
7.80000	.00000	.00000000							
7.90000	.00000	.00000000							
8.00000	.00000	.00000000							
8.10000	.00000	.00000000							
8.20000	.00000	.00000000							
8.30000	.00000	.00000000							
8.40000	.00000	.00000000							
8.50000	.00000	.00000000							
8.60000	.00000	.00000000							
8.70000	.00000	.00000000							
8.80000	.00000	.00000000							
8.90000	.00000	.00000000							
9.00000	.00000	.00000000							
9.10000	.00000	.00000000							
9.20000	.00000	.00000000							
9.30000	.00000	.00000000							
9.40000	.00000	.00000000							
9.50000	.00000	.00000000							
9.60000	.00000	.00000000							
9.70000	.00000	.00000000							
9.80000	.00000	.00000000							
9.90000	.00000	.00000000							
10.00000	.00000	.00000000							

BUS SIMULATION PROGRAM										DATE 29 MAR 1977	PAGE	0004
1800.00	.00	.00	.00	.00	.00	.00	.00	.00	.00			
-180.00	.00	190.40	281.00	344.70	447.90	531.00	612.70	697.30				
34.00	34.00	34.00	42.42	50.63	59.40	68.80	78.75	89.56				
.00	10.00	20.00	29.00	37.50	46.10	54.80	63.50	71.00				
.00	.00	.00	.00	.00	.00	.00	.00	.00				
2000.00	.00	210.00	293.60	369.50	440.10	500.70	559.10	615.20				
-210.00	.00	42.00	44.00	53.00	60.00	75.91	86.80	97.50				
.00	12.45	24.86	33.54	42.20	50.85	59.53	68.16	76.00				
.00	.00	.00	.00	.00	.00	.00	.00	.00				
2200.00	.00	236.00	304.60	373.10	442.60	512.30	582.50	651.70				
.00	50.00	50.00	57.40	65.40	73.80	83.00	92.85	104.40				
.00	18.00	30.90	39.24	47.60	55.55	64.25	72.66	81.00				
.00	.00	.00	.00	.00	.00	.00	.00	.00				
FIRST LINE IN 44-45												
800	2200	7	0	100	50	1	100	0				
800	2200	7	-50	950	10	1	100	0				
W21-ENGINE TEST												
200	2200	7	0	100	50	1	100	0				
0	000	1000	1000	1000	1000	1000	1000	1000				
1	1000	1000	1000	1000	1000	1000	1000	1000				
2	1000	1000	1000	1000	1000	1000	1000	1000				
3	1000	1000	1000	1000	1000	1000	1000	1000				
4	1000	1000	1000	1000	1000	1000	1000	1000				
5	1000	1000	1000	1000	1000	1000	1000	1000				
6	1000	1000	1000	1000	1000	1000	1000	1000				
7	1000	1000	1000	1000	1000	1000	1000	1000				
8	1000	1000	1000	1000	1000	1000	1000	1000				
9	1000	1000	1000	1000	1000	1000	1000	1000				
10	1000	1000	1000	1000	1000	1000	1000	1000				
11	1000	1000	1000	1000	1000	1000	1000	1000				
12	1000	1000	1000	1000	1000	1000	1000	1000				
13	1000	1000	1000	1000	1000	1000	1000	1000				
14	1000	1000	1000	1000	1000	1000	1000	1000				
15	1000	1000	1000	1000	1000	1000	1000	1000				
16	1000	1000	1000	1000	1000	1000	1000	1000				
17	1000	1000	1000	1000	1000	1000	1000	1000				
18	1000	1000	1000	1000	1000	1000	1000	1000				
19	1000	1000	1000	1000	1000	1000	1000	1000				
20	1000	1000	1000	1000	1000	1000	1000	1000				
21	1000	1000	1000	1000	1000	1000	1000	1000				
22	1000	1000	1000	1000	1000	1000	1000	1000				
23	1000	1000	1000	1000	1000	1000	1000	1000				
24	1000	1000	1000	1000	1000	1000	1000	1000				
25	1000	1000	1000	1000	1000	1000	1000	1000				
26	1000	1000	1000	1000	1000	1000	1000	1000				
27	1000	1000	1000	1000	1000	1000	1000	1000				
28	1000	1000	1000	1000	1000	1000	1000	1000				
29	1000	1000	1000	1000	1000	1000	1000	1000				
30	1000	1000	1000	1000	1000	1000	1000	1000				
31	1000	1000	1000	1000	1000	1000	1000	1000				
32	1000	1000	1000	1000	1000	1000	1000	1000				
33	1000	1000	1000	1000	1000	1000	1000	1000				
34	1000	1000	1000	1000	1000	1000	1000	1000				
35	1000	1000	1000	1000	1000	1000	1000	1000				
36	1000	1000	1000	1000	1000	1000	1000	1000				
37	1000	1000	1000	1000	1000	1000	1000	1000				
38	1000	1000	1000	1000	1000	1000	1000	1000				
39	1000	1000	1000	1000	1000	1000	1000	1000				
40	1000	1000	1000	1000	1000	1000	1000	1000				
41	1000	1000	1000	1000	1000	1000	1000	1000				
42	1000	1000	1000	1000	1000	1000	1000	1000				
43	1000	1000	1000	1000	1000	1000	1000	1000				
44	1000	1000	1000	1000	1000	1000	1000	1000				
45	1000	1000	1000	1000	1000	1000	1000	1000				
46	1000	1000	1000	1000	1000	1000	1000	1000				
47	1000	1000	1000	1000	1000	1000	1000	1000				
48	1000	1000	1000	1000	1000	1000	1000	1000				
49	1000	1000	1000	1000	1000	1000	1000	1000				
50	1000	1000	1000	1000	1000	1000	1000	1000				
51	1000	1000	1000	1000	1000	1000	1000	1000				
52	1000	1000	1000	1000	1000	1000	1000	1000				
53	1000	1000	1000	1000	1000	1000	1000	1000				
54	1000	1000	1000	1000	1000	1000	1000	1000				
55	1000	1000	1000	1000	1000	1000	1000	1000				
56	1000	1000	1000	1000	1000	1000	1000	1000				
57	1000	1000	1000	1000	1000	1000	1000	1000				
58	1000	1000	1000	1000	1000	1000	1000	1000				

[illegible]

BUS SIMULATION PROGRAM				VEHICLE PARAMETERS USED FOR SIMULATION				DATE 29 MAR 1977		PAGE 0006	
2.5 MPHRS				**BUS SIMULATION**				25 MPH			
TORQUE CONVERTER TC490				24300 LBS				TRANSMISSION V730			
-----VEHICLE CHARACTERISTICS-----				-----TORQUE CONVERTER-----				-----TRANSMISSION-----			
REAR AXLE RATIO				5.14	SPEED		TORQUE	1/K**2	GEAR RATIOS		SCHEDULE
MASS (LBS)				24300.0	RATIO		RATIO	(10***4)			
MASS ON DRIVE WHEELS (LBS)				12175.0							
FRONTAL AREA (SQ FT)				75.0							
COEFFICIENT OF ROLLING FRICTION				.0080	.000	2.440	2.5121	1ST 2.067			
DRAO COEFFICIENT				.700	.100	2.540	2.2665	2ND 1.000		LACKUP AT 28.0 MPH	
TIRE STATIC RADIUS (FT)				1.703	.000	2.170	2.2118	3RD 1.000		UNLOCK AT 8.6 MPH	
ENGINE INERTIA (LBS*IN**2)				37.54	.000	1.925	2.0066	4TH .000		UPSHIFT 1-2 920 RPM	
75% CONVD. TURBINE INERTIA				2.00	.000	1.502	1.9483	5TH .000		UPSHIFT 2-3 1560 RPM	
TRANSMISSION INERTIA (3RD GEAR)				1.00	.000	1.776	1.8914	6TH .000		UPSHIFT 3-2 1370 RPM	
REAR AXLE INERTIA				4.00	.000	1.612	1.8553	BEVEL .67		DOWNSHIFT 2-1 550 RPM	
INERTIA OF DRIVE WHEELS				45.52	.000	1.023	1.7604				
STATIC TIRE FRICTION COEF.				.80	.000	1.440	1.7174				
SLIPPING TIRE FRICTION COEF.				.08	.700	1.277	1.5762				
WHEEL BASE (IN)				78.00	.750	1.193	1.4481				
CHUNK OF DRIVING BELTWAY (IN)				14.00	.000	1.125	1.5302				
SOLE THROTTLE SHIFTER				.03	.000	1.053	1.2979				
TRANSMISSION SHIFTER TIME (SEC)				.00	.002	.998	1.1697				
DELAY TIME AFTER SHIFT (SEC)				.75	.012	.998	.8120				
EMERGENCY TEMPERATURE (F)				60.0	.025	.998	.7121				
BAROMETRIC PRESSURE (PSI)				14.1747	.025	.998	.7103				
AIR DENSITY (LBS/FT**3)				.0737	1.000	.998	.7100				
ENGINE SCALE FACTOR				1.000	1.250	.998	.4400				
WHEEL DENSITY (LBS/IN**3)				7.71	1.000	.998	.4400				
-----TIRE EXPANSION-----				DRIVESHAFT ROAD LOAD							
VEHICLE SPEED				DRIVE CYCLE				-----TORQUE TABLE-----			
SPEED				STEPS/MILE				VEHICLE ROAD LOAD			
0.0				5				SPEED TORQUE			
10.0				MAX. ACCEL. 2.5 MPHRS				.0			
20.0				DECLERATION 2.5 MPHRS				10.0			
30.0				CRUISE SPEED 25.0 MPH				20.0			
40.0								30.0			
50.0								40.0			
60.0								50.0			
70.0								60.0			
80.0								70.0			
90.0								80.0			
100.0								90.0			
								100.0			
								• NO LOAD EQUATION IS USED •			

TIME DIST. SPEED			ACCEL.			SPEED TORQUE POWER			FUEL RATE			ACCUMU			TORQUE CONVERSION			DRIVE/HA GE		
(SEC)	(MI)	(MPH)	(MPH/SEC)	(MPH)	(FT/LB)	(HP)	(LB/HR)	(GPH)	(PPH)	(PPH)	(PPH)	(PPH)	(PPH)	(PPH)	(PPH)	(PPH)	(PPH)	(PPH)	(PPH)	(PPH)
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1.00	0.00	2.57	2.57	2.57	37.4	37.4	37.4	37.4	37.4	37.4	37.4	37.4	37.4	37.4	37.4	37.4	37.4	37.4	37.4	37.4
2.00	0.01	5.14	2.57	2.57	105.5	345.8	69.5	43.5	30.43	1.20	0.70	350	1.893	674	947	958	1.1	937	967	1.1
3.00	0.03	7.71	2.57	2.57	115.4	370.6	73.5	43.5	30.43	1.33	0.96	473	1.623	756	951	953	1.1	937	967	1.1
4.00	0.05	10.28	2.57	2.57	124.4	439.7	107.5	38.0	30.43	1.48	1.18	585	1.465	864	956	960	1.1	937	967	1.1
5.00	0.07	12.85	2.57	2.57	133.4	466.7	129.3	37.0	30.43	1.78	1.35	675	1.318	895	960	963	1.1	937	967	1.1
6.00	0.13	15.42	2.57	2.57	151.4	536.0	154.6	37.7	30.43	1.87	1.48	748	1.196	899	963	966	1.1	937	967	1.1
7.00	0.17	17.99	2.57	2.57	161.0	565.8	162.3	37.6	30.43	1.75	1.57	821	1.058	899	965	966	1.1	937	967	1.1
8.00	0.22	20.56	2.57	2.57	163.7	665.5	223.3	37.4	30.43	1.92	1.63	837	1.379	883	965	972	1.1	937	967	1.1
9.00	0.28	23.13	2.57	2.57	176.7	703.3	228.3	37.5	30.43	1.97	1.68	867	1.275	896	965	977	1.1	937	967	1.1
10.00	0.33	25.70	2.57	2.57	171.7	117.5	26.4	76.9	30.67	5.87	1.76	744	1.203	898	969	963	1.1	937	967	1.1
11.00	0.38	28.27	2.57	2.57	165.6	94.0	23.0	9.73	20.77	8.67	2.01	1.000	960	960	958	947	1.1	937	967	1.1
12.00	0.45	30.84	2.57	2.57	124.6	94.4	23.1	8.99	20.80	8.67	2.26	1.000	960	960	958	947	1.1	937	967	1.1
13.00	0.56	33.41	2.57	2.57	124.6	94.4	23.1	8.99	20.80	8.67	2.49	1.000	960	960	958	947	1.1	937	967	1.1
14.00	0.63	35.98	2.57	2.57	124.6	94.4	23.1	8.99	20.80	8.67	2.70	1.000	960	960	958	947	1.1	937	967	1.1
15.00	0.71	38.55	2.57	2.57	124.6	94.4	23.1	8.99	20.80	8.67	2.90	1.000	960	960	958	947	1.1	937	967	1.1
16.00	0.77	41.12	2.57	2.57	124.6	94.4	23.1	8.99	20.80	8.67	3.08	1.000	960	960	958	947	1.1	937	967	1.1
17.00	0.84	43.69	2.57	2.57	124.6	94.4	23.1	8.99	20.80	8.67	3.26	1.000	960	960	958	947	1.1	937	967	1.1
18.00	0.91	46.26	2.57	2.57	124.6	94.4	23.1	8.99	20.80	8.67	3.42	1.000	960	960	958	947	1.1	937	967	1.1
19.00	0.97	48.83	2.57	2.57	124.6	94.4	23.1	8.99	20.80	8.67	3.58	1.000	960	960	958	947	1.1	937	967	1.1
20.00	1.04	51.40	2.57	2.57	124.6	94.4	23.1	8.99	20.80	8.67	3.72	1.000	960	960	958	947	1.1	937	967	1.1
21.00	1.11	53.97	2.57	2.57	124.6	94.4	23.1	8.99	20.80	8.67	3.86	1.000	960	960	958	947	1.1	937	967	1.1
22.00	1.18	56.54	2.57	2.57	124.6	94.4	23.1	8.99	20.80	8.67	3.99	1.000	960	960	958	947	1.1	937	967	1.1
23.00	1.25	59.11	2.57	2.57	124.6	94.4	23.1	8.99	20.80	8.67	4.11	1.000	960	960	958	947	1.1	937	967	1.1
24.00	1.32	61.68	2.57	2.57	124.6	94.4	23.1	8.99	20.80	8.67	4.23	1.000	960	960	958	947	1.1	937	967	1.1
25.00	1.39	64.25	2.57	2.57	124.6	94.4	23.1	8.99	20.80	8.67	4.34	1.000	960	960	958	947	1.1	937	967	1.1
26.00	1.46	66.82	2.57	2.57	124.6	94.4	23.1	8.99	20.80	8.67	4.44	1.000	960	960	958	947	1.1	937	967	1.1
27.00	1.53	69.39	2.57	2.57	124.6	94.4	23.1	8.99	20.80	8.67	4.55	1.000	960	960	958	947	1.1	937	967	1.1
28.00	1.60	71.96	2.57	2.57	124.6	94.4	23.1	8.99	20.80	8.67	4.66	1.000	960	960	958	947	1.1	937	967	1.1
29.00	1.67	74.53	2.57	2.57	124.6	94.4	23.1	8.99	20.80	8.67	4.73	1.000	960	960	958	947	1.1	937	967	1.1
30.00	1.72	77.10	2.57	2.57	124.6	94.4	23.1	8.99	20.80	8.67	4.80	1.000	960	960	958	947	1.1	937	967	1.1
31.00	1.79	79.67	2.57	2.57	124.6	94.4	23.1	8.99	20.80	8.67	4.88	1.000	960	960	958	947	1.1	937	967	1.1
32.00	1.82	81.87	2.57	2.57	124.6	94.4	23.1	8.99	20.80	8.67	4.95	1.000	960	960	958	947	1.1	937	967	1.1
33.00	1.85	84.07	2.57	2.57	124.6	94.4	23.1	8.99	20.80	8.67	5.02	1.000	960	960	958	947	1.1	937	967	1.1
34.00	1.87	86.27	2.57	2.57	124.6	94.4	23.1	8.99	20.80	8.67	5.09	1.000	960	960	958	947	1.1	937	967	1.1
35.00	1.90	88.47	2.57	2.57	124.6	94.4	23.1	8.99	20.80	8.67	5.16	1.000	960	960	958	947	1.1	937	967	1.1
36.00	1.93	90.67	2.57	2.57	124.6	94.4	23.1	8.99	20.80	8.67	5.23	1.000	960	960	958	947	1.1	937	967	1.1
37.00	1.95	92.87	2.57	2.57	124.6	94.4	23.1	8.99	20.80	8.67	5.30	1.000	960	960	958	947	1.1	937	967	1.1
38.00	1.98	95.07	2.57	2.57	124.6	94.4	23.1	8.99	20.80	8.67	5.37	1.000	960	960	958	947	1.1	937	967	1.1
39.00	1.99	97.27	2.57	2.57	124.6	94.4	23.1	8.99	20.80	8.67	5.44	1.000	960	960	958	947	1.1	937	967	1.1
40.00	2.00	99.47	2.57	2.57	124.6	94.4	23.1	8.99	20.80	8.67	5.51	1.000	960	960	958	947	1.1	937	967	1.1
41.00	2.03	101.67	2.57	2.57	124.6	94.4	23.1	8.99	20.80	8.67	5.58	1.000	960	960	958	947	1.1	937	967	1.1
42.00	2.05	103.87	2.57	2.57	124.6	94.4	23.1	8.99	20.80	8.67	5.65	1.000	960	960	958	947	1.1	937	967	1.1
43.00	2.07	106.07	2.57	2.57	124.6	94.4	23.1	8.99	20.80	8.67	5.72	1.000	960	960	958	947	1.1	937	967	1.1
44.00	2.09	108.27	2.57	2.57	124.6	94.4	23.1	8.99	20.80	8.67	5.79	1.000	960	960	958	947	1.1	937	967	1.1
45.00	2.10	110.47	2.57	2.57	124.6	94.4	23.1	8.99	20.80	8.67	5.86	1.000	960	960	958	947	1.1	937	967	1.1
46.00	2.13	112.67	2.57	2.57	124.6	94.4	23.1	8.99	20.80	8.67	5.93	1.000	960	960	958	947	1.1	937	967	1.1
47.00	2.15	114.87	2.57	2.57	124.6	94.4	23.1	8.99	20.80	8.67	6.00	1.000	960	960	958	947	1.1	937	967	1.1
48.00	2.17	117.07	2.57	2.57	124.6	94.4	23.1	8.99	20.80	8.67	6.07	1.000	960	960	958	947	1.1	937	967	1.1
49.00	2.19	119.27	2.57	2.57	124.6	94.4	23.1	8.99	20.80	8.67	6.14	1.000	960	960	958	947	1.1	937	967	1.1
50.00	2.20	121.47	2.57	2.57	124.6	94.4	23.1	8.99	20.80	8.67	6.21	1.000	960	960	958	947	1.1	937	967	1.1

VEHICLE				ENGINE				FUEL RATE				ACCUMU		TORQUE CONVERTER		DRIVE TRAIN		
TIME	DIST.	SPEED	ACCEL.	SPEED	TORQUE	POWER	HP-RR	INSTANTAN	AVG	LATIVE	SPEED	TORQUE	EFFIC	TR	RA	GE	EFF.	AR
(SEC)	(FT)	(MPH)	(MPH/SEC)	(MPH)	(FT-LO)	(HP)	(%)	(LB/HR)	(MPG)	(MPG)	(MPG)	(MPG)	(%)	(%)	(%)	(%)	(%)	(%)
48.00	194	0.0	0.00	806	247.1	37.9	476	16.52	0.00	4.10	0.000	2.460	0.00	0.937	0.967	1.		
49.00	194	0.0	0.00	806	247.1	37.9	476	16.52	0.00	4.04	0.000	2.460	0.00	0.937	0.967	1.		
50.00	194	0.0	0.00	806	247.1	37.9	476	16.52	0.00	3.99	0.000	2.460	0.00	0.937	0.967	1.		
51.00	194	0.0	0.00	806	247.1	37.9	476	16.52	0.00	3.94	0.000	2.460	0.00	0.937	0.967	1.		
52.00	194	0.0	0.00	806	247.1	37.9	476	16.52	0.00	3.89	0.000	2.460	0.00	0.937	0.967	1.		
53.00	194	0.0	0.00	806	247.1	37.9	476	16.52	0.00	3.84	0.000	2.460	0.00	0.937	0.967	1.		
54.00	194	0.0	0.00	806	247.1	37.9	476	16.52	0.00	3.79	0.000	2.460	0.00	0.937	0.967	1.		
55.00	194	0.0	0.00	806	247.1	37.9	476	16.52	0.00	3.74	0.000	2.460	0.00	0.937	0.967	1.		
56.00	194	0.0	0.00	806	247.1	37.9	476	16.52	0.00	3.69	0.000	2.460	0.00	0.937	0.967	1.		
57.00	194	0.0	0.00	806	247.1	37.9	476	16.52	0.00	3.64	0.000	2.460	0.00	0.937	0.967	1.		
58.00	194	0.0	0.00	806	247.1	37.9	476	16.52	0.00	3.59	0.000	2.460	0.00	0.937	0.967	1.		
59.00	194	0.0	0.00	806	247.1	37.9	476	16.52	0.00	3.54	0.000	2.460	0.00	0.937	0.967	1.		
60.00	194	0.0	0.00	806	247.1	37.9	476	16.52	0.00	3.49	0.000	2.460	0.00	0.937	0.967	1.		
61.00	194	0.0	0.00	806	247.1	37.9	476	16.52	0.00	3.44	0.000	2.460	0.00	0.937	0.967	1.		
62.00	194	0.0	0.00	806	247.1	37.9	476	16.52	0.00	3.39	0.000	2.460	0.00	0.937	0.967	1.		
63.00	194	0.0	0.00	806	247.1	37.9	476	16.52	0.00	3.34	0.000	2.460	0.00	0.937	0.967	1.		
64.00	194	0.0	0.00	806	247.1	37.9	476	16.52	0.00	3.29	0.000	2.460	0.00	0.937	0.967	1.		
65.00	194	0.0	0.00	806	247.1	37.9	476	16.52	0.00	3.24	0.000	2.460	0.00	0.937	0.967	1.		
66.00	194	0.0	0.00	806	247.1	37.9	476	16.52	0.00	3.19	0.000	2.460	0.00	0.937	0.967	1.		
67.00	194	0.0	0.00	806	247.1	37.9	476	16.52	0.00	3.14	0.000	2.460	0.00	0.937	0.967	1.		
68.00	194	0.0	0.00	806	247.1	37.9	476	16.52	0.00	3.09	0.000	2.460	0.00	0.937	0.967	1.		
69.00	194	0.0	0.00	806	247.1	37.9	476	16.52	0.00	3.04	0.000	2.460	0.00	0.937	0.967	1.		
70.00	194	0.0	0.00	806	247.1	37.9	476	16.52	0.00	2.99	0.000	2.460	0.00	0.937	0.967	1.		
71.00	194	0.0	0.00	806	247.1	37.9	476	16.52	0.00	2.94	0.000	2.460	0.00	0.937	0.967	1.		
72.00	194	0.0	0.00	806	247.1	37.9	476	16.52	0.00	2.89	0.000	2.460	0.00	0.937	0.967	1.		
73.00	194	0.0	0.00	806	247.1	37.9	476	16.52	0.00	2.84	0.000	2.460	0.00	0.937	0.967	1.		
74.00	194	0.0	0.00	806	247.1	37.9	476	16.52	0.00	2.79	0.000	2.460	0.00	0.937	0.967	1.		
75.00	194	0.0	0.00	806	247.1	37.9	476	16.52	0.00	2.74	0.000	2.460	0.00	0.937	0.967	1.		
76.00	194	0.0	0.00	806	247.1	37.9	476	16.52	0.00	2.69	0.000	2.460	0.00	0.937	0.967	1.		
77.00	194	0.0	0.00	806	247.1	37.9	476	16.52	0.00	2.64	0.000	2.460	0.00	0.937	0.967	1.		
78.00	194	0.0	0.00	806	247.1	37.9	476	16.52	0.00	2.59	0.000	2.460	0.00	0.937	0.967	1.		
79.00	194	0.0	0.00	806	247.1	37.9	476	16.52	0.00	2.54	0.000	2.460	0.00	0.937	0.967	1.		
80.00	194	0.0	0.00	806	247.1	37.9	476	16.52	0.00	2.49	0.000	2.460	0.00	0.937	0.967	1.		
81.00	194	0.0	0.00	806	247.1	37.9	476	16.52	0.00	2.44	0.000	2.460	0.00	0.937	0.967	1.		
82.00	194	0.0	0.00	806	247.1	37.9	476	16.52	0.00	2.39	0.000	2.460	0.00	0.937	0.967	1.		
83.00	194	0.0	0.00	806	247.1	37.9	476	16.52	0.00	2.34	0.000	2.460	0.00	0.937	0.967	1.		
84.00	194	0.0	0.00	806	247.1	37.9	476	16.52	0.00	2.29	0.000	2.460	0.00	0.937	0.967	1.		
85.00	194	0.0	0.00	806	247.1	37.9	476	16.52	0.00	2.24	0.000	2.460	0.00	0.937	0.967	1.		
86.00	194	0.0	0.00	806	247.1	37.9	476	16.52	0.00	2.19	0.000	2.460	0.00	0.937	0.967	1.		
87.00	194	0.0	0.00	806	247.1	37.9	476	16.52	0.00	2.14	0.000	2.460	0.00	0.937	0.967	1.		
88.00	194	0.0	0.00	806	247.1	37.9	476	16.52	0.00	2.09	0.000	2.460	0.00	0.937	0.967	1.		
89.00	194	0.0	0.00	806	247.1	37.9	476	16.52	0.00	2.04	0.000	2.460	0.00	0.937	0.967	1.		
90.00	194	0.0	0.00	806	247.1	37.9	476	16.52	0.00	1.99	0.000	2.460	0.00	0.937	0.967	1.		
91.00	194	0.0	0.00	806	247.1	37.9	476	16.52	0.00	1.94	0.000	2.460	0.00	0.937	0.967	1.		
92.00	194	0.0	0.00	806	247.1	37.9	476	16.52	0.00	1.89	0.000	2.460	0.00	0.937	0.967	1.		
93.00	194	0.0	0.00	806	247.1	37.9	476	16.52	0.00	1.84	0.000	2.460	0.00	0.937	0.967	1.		
94.00	194	0.0	0.00	806	247.1	37.9	476	16.52	0.00	1.79	0.000	2.460	0.00	0.937	0.967	1.		
95.00	194	0.0	0.00	806	247.1	37.9	476	16.52	0.00	1.74	0.000	2.460	0.00	0.937	0.967	1.		
96.00	194	0.0	0.00	806	247.1	37.9	476	16.52	0.00	1.69	0.000	2.460	0.00	0.937	0.967	1.		
97.00	194	0.0	0.00	806	247.1	37.9	476	16.52	0.00	1.64	0.000	2.460	0.00	0.937	0.967	1.		
98.00	194	0.0	0.00	806	247.1	37.9	476	16.52	0.00	1.59	0.000	2.460	0.00	0.937	0.967	1.		
99.00	194	0.0	0.00	806	247.1	37.9	476	16.52	0.00	1.54	0.000	2.460	0.00	0.937	0.967	1.		
100.00	194	0.0	0.00	806	247.1	37.9	476	16.52	0.00	1.49	0.000	2.460	0.00	0.937	0.967	1.		

BUS SIMULATION PROGRAM

2.5 MPHPS

BUS SIMULATION

DATE 29 MAR 1977

PAGE

0009

TORQUE CONVERTER TC400

24350 TB.

TRANSMISSION V730

TIME	DIST.	VEHICLE SPEED (MPH)	ACCEL. (MPH/SEC)	ENGINE SPEED (RPM)	TORQUE (FT-LB)	POWER (HP)	FUEL RATE (LB/HR)	ACCUMU LATIVE (MPG)	TORQUE CONVERTER SPEED (RPM)	TORQUE EFFIC	DRIVE TRAIN TR EFF.	RANGE EFF.				
(SECT) <td>(FT)<td>(MPH)<td>(MPH/SEC)<td>(RPM)<td>(FT-LB)<td>(HP)<td>(LB/HR)<td>(MPG)<td>(RPM)<td></td><td></td><td>(GE)</td></td></td></td></td></td></td></td></td></td>	(FT) <td>(MPH)<td>(MPH/SEC)<td>(RPM)<td>(FT-LB)<td>(HP)<td>(LB/HR)<td>(MPG)<td>(RPM)<td></td><td></td><td>(GE)</td></td></td></td></td></td></td></td></td>	(MPH) <td>(MPH/SEC)<td>(RPM)<td>(FT-LB)<td>(HP)<td>(LB/HR)<td>(MPG)<td>(RPM)<td></td><td></td><td>(GE)</td></td></td></td></td></td></td></td>	(MPH/SEC) <td>(RPM)<td>(FT-LB)<td>(HP)<td>(LB/HR)<td>(MPG)<td>(RPM)<td></td><td></td><td>(GE)</td></td></td></td></td></td></td>	(RPM) <td>(FT-LB)<td>(HP)<td>(LB/HR)<td>(MPG)<td>(RPM)<td></td><td></td><td>(GE)</td></td></td></td></td></td>	(FT-LB) <td>(HP)<td>(LB/HR)<td>(MPG)<td>(RPM)<td></td><td></td><td>(GE)</td></td></td></td></td>	(HP) <td>(LB/HR)<td>(MPG)<td>(RPM)<td></td><td></td><td>(GE)</td></td></td></td>	(LB/HR) <td>(MPG)<td>(RPM)<td></td><td></td><td>(GE)</td></td></td>	(MPG) <td>(RPM)<td></td><td></td><td>(GE)</td></td>	(RPM) <td></td> <td></td> <td>(GE)</td>			(GE)				
95.00	336	0.00	0.00	806	247.1	37.9	4.35	16.52	0.00	4.20	0.00	2.460	0.00	.937	.967	1.
96.00	336	0.00	0.00	806	247.1	37.9	4.36	16.52	0.00	4.17	0.00	2.460	0.00	.937	.967	1.
97.00	336	0.00	0.00	806	247.1	37.9	4.36	16.52	0.00	4.14	0.00	2.460	0.00	.937	.967	1.
98.00	336	0.00	0.00	806	247.1	37.9	4.36	16.52	0.00	4.12	0.00	2.460	0.00	.937	.967	1.
99.00	336	0.00	0.00	806	247.1	37.9	4.36	16.52	0.00	4.09	0.00	2.460	0.00	.937	.967	1.
100.00	336	0.00	0.00	806	247.1	37.9	4.36	16.52	0.00	4.06	0.00	2.460	0.00	.937	.967	1.
101.00	336	0.00	0.00	806	247.1	37.9	4.36	16.52	0.00	4.04	0.00	2.460	0.00	.937	.967	1.
102.00	336	0.00	0.00	806	247.1	37.9	4.36	16.52	0.00	4.01	0.00	2.460	0.00	.937	.967	1.
103.00	336	0.00	0.00	806	247.1	37.9	4.36	16.52	0.00	3.98	0.00	2.460	0.00	.937	.967	1.
104.00	336	0.00	0.00	806	247.1	37.9	4.36	16.52	0.00	3.96	0.00	2.460	0.00	.937	.967	1.
105.00	336	0.00	0.00	806	247.1	37.9	4.36	16.52	0.00	3.93	0.00	2.460	0.00	.937	.967	1.
106.00	336	0.00	0.00	806	247.1	37.9	4.36	16.52	0.00	3.91	0.00	2.460	0.00	.937	.967	1.
107.00	336	0.00	0.00	806	247.1	37.9	4.36	16.52	0.00	3.88	0.00	2.460	0.00	.937	.967	1.
108.00	336	0.00	0.00	806	247.1	37.9	4.36	16.52	0.00	3.86	0.00	2.460	0.00	.937	.967	1.
109.00	336	0.00	0.00	806	247.1	37.9	4.36	16.52	0.00	3.84	0.00	2.460	0.00	.937	.967	1.
110.00	336	0.00	0.00	806	247.1	37.9	4.36	16.52	0.00	3.81	0.00	2.460	0.00	.937	.967	1.
111.00	336	0.00	0.00	806	247.1	37.9	4.36	16.52	0.00	3.78	0.00	2.460	0.00	.937	.967	1.
112.00	336	0.00	0.00	806	247.1	37.9	4.36	16.52	0.00	3.75	0.00	2.460	0.00	.937	.967	1.
113.00	336	0.00	0.00	806	247.1	37.9	4.36	16.52	0.00	3.72	0.00	2.460	0.00	.937	.967	1.
114.00	336	0.00	0.00	806	247.1	37.9	4.36	16.52	0.00	3.69	0.00	2.460	0.00	.937	.967	1.
115.00	336	0.00	0.00	806	247.1	37.9	4.36	16.52	0.00	3.66	0.00	2.460	0.00	.937	.967	1.
116.00	336	0.00	0.00	806	247.1	37.9	4.36	16.52	0.00	3.63	0.00	2.460	0.00	.937	.967	1.
117.00	336	0.00	0.00	806	247.1	37.9	4.36	16.52	0.00	3.60	0.00	2.460	0.00	.937	.967	1.
118.00	336	0.00	0.00	806	247.1	37.9	4.36	16.52	0.00	3.57	0.00	2.460	0.00	.937	.967	1.
119.00	336	0.00	0.00	806	247.1	37.9	4.36	16.52	0.00	3.54	0.00	2.460	0.00	.937	.967	1.
120.00	336	0.00	0.00	806	247.1	37.9	4.36	16.52	0.00	3.51	0.00	2.460	0.00	.937	.967	1.
121.00	336	0.00	0.00	806	247.1	37.9	4.36	16.52	0.00	3.48	0.00	2.460	0.00	.937	.967	1.
122.00	336	0.00	0.00	806	247.1	37.9	4.36	16.52	0.00	3.45	0.00	2.460	0.00	.937	.967	1.
123.00	336	0.00	0.00	806	247.1	37.9	4.36	16.52	0.00	3.42	0.00	2.460	0.00	.937	.967	1.
124.00	336	0.00	0.00	806	247.1	37.9	4.36	16.52	0.00	3.39	0.00	2.460	0.00	.937	.967	1.
125.00	336	0.00	0.00	806	247.1	37.9	4.36	16.52	0.00	3.36	0.00	2.460	0.00	.937	.967	1.
126.00	336	0.00	0.00	806	247.1	37.9	4.36	16.52	0.00	3.33	0.00	2.460	0.00	.937	.967	1.
127.00	336	0.00	0.00	806	247.1	37.9	4.36	16.52	0.00	3.30	0.00	2.460	0.00	.937	.967	1.
128.00	336	0.00	0.00	806	247.1	37.9	4.36	16.52	0.00	3.27	0.00	2.460	0.00	.937	.967	1.
129.00	336	0.00	0.00	806	247.1	37.9	4.36	16.52	0.00	3.24	0.00	2.460	0.00	.937	.967	1.
130.00	336	0.00	0.00	806	247.1	37.9	4.36	16.52	0.00	3.21	0.00	2.460	0.00	.937	.967	1.
131.00	336	0.00	0.00	806	247.1	37.9	4.36	16.52	0.00	3.18	0.00	2.460	0.00	.937	.967	1.
132.00	336	0.00	0.00	806	247.1	37.9	4.36	16.52	0.00	3.15	0.00	2.460	0.00	.937	.967	1.
133.00	336	0.00	0.00	806	247.1	37.9	4.36	16.52	0.00	3.12	0.00	2.460	0.00	.937	.967	1.
134.00	336	0.00	0.00	806	247.1	37.9	4.36	16.52	0.00	3.09	0.00	2.460	0.00	.937	.967	1.
135.00	336	0.00	0.00	806	247.1	37.9	4.36	16.52	0.00	3.06	0.00	2.460	0.00	.937	.967	1.
136.00	336	0.00	0.00	806	247.1	37.9	4.36	16.52	0.00	3.03	0.00	2.460	0.00	.937	.967	1.
137.00	336	0.00	0.00	806	247.1	37.9	4.36	16.52	0.00	3.00	0.00	2.460	0.00	.937	.967	1.
138.00	336	0.00	0.00	806	247.1	37.9	4.36	16.52	0.00	2.97	0.00	2.460	0.00	.937	.967	1.
139.00	336	0.00	0.00	806	247.1	37.9	4.36	16.52	0.00	2.94	0.00	2.460	0.00	.937	.967	1.
140.00	336	0.00	0.00	806	247.1	37.9	4.36	16.52	0.00	2.91	0.00	2.460	0.00	.937	.967	1.
141.00	336	0.00	0.00	806	247.1	37.9	4.36	16.52	0.00	2.88	0.00	2.460	0.00	.937	.967	1.

TRANSMISSION V730

TIME	VEHICLE			ENGINE			FUEL RATE			ACCUMU	TORQUE CONVERTER			DRIVETRAIN			
	DIST.	SPEED	ACCEL.	SPEED	THROTTLE	PAIR	(LB	INSTANTANEOUS	PERCENT		LATIVE	SPEED	TORQUE	EFFIC	TR	EFF.	GR
(SEC)	(MI)	(MPH)	(MP/SEC)	(MPH)	(FT-LB)	(HP)	(HP-FT)	(L/HR)	(PPH)		(PPG)	RATIO	RATIO	ENCY	EFF.	EFF.	AR
236.00	1.842	27.00	0.000	1286.0	94.4	23.1	8.89	20.60	8.67	3.79	1.000	.960	.960	.958	.947	2.0	
237.00	1.851	25.00	0.000	1230.0	94.4	23.1	8.89	20.60	8.67	3.81	1.000	.960	.960	.958	.947	2.0	
238.00	1.854	25.00	0.000	1246.0	94.4	23.1	8.89	20.60	8.67	3.83	1.000	.960	.960	.958	.947	2.0	
239.00	1.864	25.00	0.000	1245.0	94.4	23.1	8.89	20.60	8.67	3.84	1.000	.960	.960	.958	.947	2.0	
240.00	1.816	25.00	0.000	1245.0	94.4	23.1	8.89	20.60	8.67	3.86	1.000	.960	.960	.958	.947	2.0	
241.00	1.817	25.00	0.000	1246.0	94.4	23.1	8.89	20.60	8.67	3.88	1.000	.960	.960	.958	.947	2.0	
242.00	1.824	25.00	0.000	1246.0	94.4	23.1	8.89	20.60	8.67	3.89	1.000	.960	.960	.958	.947	2.0	
243.00	1.831	25.00	0.000	1246.0	94.4	23.1	8.89	20.60	8.67	3.91	1.000	.960	.960	.958	.947	2.0	
244.00	1.837	25.00	0.000	1245.0	94.4	23.1	8.89	20.60	8.67	3.92	1.000	.960	.960	.958	.947	2.0	
245.00	1.844	25.00	0.000	1245.0	94.4	23.1	8.89	20.60	8.67	3.94	1.000	.960	.960	.958	.947	2.0	
246.00	1.851	25.00	0.000	1246.0	94.4	23.1	8.89	20.60	8.67	3.96	1.000	.960	.960	.958	.947	2.0	
247.00	1.854	24.44	-2.000	1243.0	77.7	13.0	8.89	20.24	8.45	3.97	1.000	.960	.961	.965	.937	2.0	
248.00	1.865	22.00	-2.000	1156.0	-25.2	-5.6	8.89	8.84	8.79	3.99	1.000	.960	.961	.956	.944	2.0	
249.00	1.871	17.68	-2.000	1029.0	114.7	22.5	7.35	17.85	8.85	4.00	1.000	.960	.960	.958	.950	2.0	
250.00	1.876	17.68	-2.000	901.0	157.6	33.9	5.13	17.39	7.20	4.01	1.000	.960	.969	1.020	.968	2.0	
251.00	1.880	17.67	-2.000	773.0	205.1	32.9	4.21	17.37	6.55	4.02	1.000	.960	.958	1.033	.972	2.0	
252.00	1.884	18.44	-2.000	666.0	213.1	35.8	4.77	17.06	5.84	4.02	1.000	.960	.964	.965	.970	1.0	
253.00	1.887	17.37	-2.000	762.0	205.6	30.2	4.17	16.33	4.76	4.02	1.000	.960	.966	.966	.963	1.0	
254.00	1.892	7.39	-2.000	612.0	337.5	40.6	3.34	16.01	3.33	4.02	.910	1.036	.935	.963	.952	1.0	
255.00	1.891	4.43	-2.000	487.0	272.2	33.3	3.67	15.53	2.88	4.02	.458	1.651	.757	.958	.956	1.0	
256.00	1.892	2.42	-2.000	493.0	238.1	37.3	4.47	16.70	1.05	4.01	.245	2.027	.449	.949	.961	1.0	
257.00	1.893	0.00	-2.000	8.77	245.3	37.9	4.76	17.53	0.00	4.03	.016	2.441	.000	.937	.967	1.0	
258.00	1.893	0.00	-2.000	5.66	247.1	37.9	4.76	16.52	0.00	3.99	.000	2.460	.000	.937	.967	1.0	
259.00	1.892	0.00	-2.000	8.55	247.1	37.9	4.76	16.52	0.00	3.98	.000	2.460	.000	.937	.967	1.0	
260.00	1.893	0.00	-2.000	8.66	247.1	37.9	4.76	16.52	0.00	3.97	.000	2.460	.000	.937	.967	1.0	
261.00	1.893	0.00	-2.000	8.55	247.1	37.9	4.76	16.52	0.00	3.96	.000	2.460	.000	.937	.967	1.0	
262.00	1.893	0.00	-2.000	8.66	247.1	37.9	4.76	16.52	0.00	3.95	.000	2.460	.000	.937	.967	1.0	
263.00	1.893	0.00	-2.000	8.66	247.1	37.9	4.76	16.52	0.00	3.94	.000	2.460	.000	.937	.967	1.0	
264.00	1.891	0.00	-2.000	8.66	247.1	37.9	4.76	16.52	0.00	3.93	.000	2.460	.000	.937	.967	1.0	
265.00	1.893	0.00	-2.000	8.55	247.1	37.9	4.76	16.52	0.00	3.92	.000	2.460	.000	.937	.967	1.0	
266.00	1.893	0.00	-2.000	8.66	247.1	37.9	4.76	16.52	0.00	3.91	.000	2.460	.000	.937	.967	1.0	
267.00	1.893	0.00	-2.000	8.55	247.1	37.9	4.76	16.52	0.00	3.90	.000	2.460	.000	.937	.967	1.0	
268.00	1.893	0.00	-2.000	8.66	247.1	37.9	4.76	16.52	0.00	3.89	.000	2.460	.000	.937	.967	1.0	
269.00	1.893	0.00	-2.000	8.66	247.1	37.9	4.76	16.52	0.00	3.88	.000	2.460	.000	.937	.967	1.0	
270.00	1.893	0.00	-2.000	8.66	247.1	37.9	4.76	16.52	0.00	3.87	.000	2.460	.000	.937	.967	1.0	
271.00	1.893	0.00	-2.000	8.66	247.1	37.9	4.76	16.52	0.00	3.87	.000	2.460	.000	.937	.967	1.0	
272.00	1.893	0.00	-2.000	8.66	247.1	37.9	4.76	16.52	0.00	3.86	.000	2.460	.000	.937	.967	1.0	
273.58	1.893	0.00	-2.000	8.55	247.1	37.9	4.76	16.52	0.00	3.85	.000	2.460	.000	.937	.967	1.0	

BUS SIMULATION PROGRAM		DATE 29 MAR 1977	PAGE 0014
FOR ITERATIONS TAKE PLACE OVER THE CYCLE			
ONE SAMPLE TAKEN DURING EACH PROGRAM ITERATION			
☐ SAMPLES FELL BELOW THE MINIMUM TORQUE ☐ SAMPLES EXCEEDED THE MAXIMUM TORQUE ☐ SAMPLES FELL BELOW THE MINIMUM SPEED ☐ SAMPLES EXCEEDED THE MAXIMUM SPEED			
MILES PER GALLON = 3.247			
GALLONS PER MILE = .250			
NUMBER OF SIGNS PER MILE = 5			
DISTANCE = .9927			
POWER-SECONDS			
DRIVE.....MOTORING			
POWER REQUIRED BY THE WHEEL	6396.16	-102.14	
POWER REQUIRED BY THE REAR AXLE	7475.83	-111.32	
POWER REQUIRED BY THE DRIVE SHAFT	7785.10	-115.35	
POWER REQUIRED BY THE TRANSM. CONVERTER	11831.44	-120.04	
POWER REQUIRED BY THE ENGINE FLYWHEEL	13438.13	-84.07	
POWER REQUIRED BY THE ACCESSORIES	1510.87		

ENGINE			TRANSMISSION			REAR AXLE	
TIME	INSTANT. ENGINE TORQUE	ACC. TORQUE	DYNAMIC FLYWHEEL TORQUE	DYNAMIC CONVERTER OUTPUT TORQUE	DYNAMIC DRIVE SHAFT TORQUE	DYNAMIC REAR AXLE OUTPUT TORQUE	GEAR
1.00	345.75	24.34	327.62	637.03	1227.53	1949.33	1*
2.00	345.83	24.84	327.96	643.30	1263.14	1916.09	1*
3.00	352.83	25.03	365.75	561.23	1103.12	1346.64	1*
4.00	439.68	27.35	422.85	541.92	1071.07	8266.54	1*
5.00	476.55	21.67	465.32	530.67	1064.68	5230.06	1*
6.00	536.00	31.94	506.94	530.55	1059.66	5223.04	1*
7.00	615.21	33.21	477.78	445.67	833.45	4350.22	2*
8.00	646.44	34.69	633.43	772.90	1042.02	5147.19	2*
9.00	732.45	37.23	663.00	752.74	1022.97	5118.25	2*
10.00	117.44	35.84	124.11	111.72	151.50	747.50	2*
11.00	94.43	27.45	67.07	56.42	75.67	347.17	2*
12.00	94.43	27.46	66.75	56.40	75.23	344.35	2*
13.00	94.43	27.46	66.75	56.24	75.43	345.94	2*
14.00	94.43	27.46	66.56	56.24	75.43	345.94	2*
15.00	94.43	27.46	66.56	56.24	75.43	345.94	2*
16.00	94.43	27.46	66.56	56.24	75.43	345.94	2*
17.00	94.43	27.46	66.56	56.24	75.43	345.94	2*
18.00	94.43	27.46	66.56	56.24	75.43	345.94	2*
19.00	94.43	27.46	66.56	56.24	75.43	345.94	2*
20.00	94.43	27.46	66.56	56.24	75.43	345.94	2*
21.00	94.43	27.46	66.56	56.24	75.43	345.94	2*
22.00	94.43	27.46	66.56	56.24	75.43	345.94	2*
23.00	94.43	27.46	66.56	56.24	75.43	345.94	2*
24.00	94.43	27.46	66.56	56.24	75.43	345.94	2*
25.00	94.43	27.46	66.56	56.24	75.43	345.94	2*
26.00	94.43	27.46	66.56	56.24	75.43	345.94	2*
27.00	94.43	27.46	66.56	56.24	75.43	345.94	2*
28.00	94.43	27.46	66.56	56.24	75.43	345.94	2*
29.00	94.43	27.46	66.56	56.24	75.43	345.94	2*
30.00	94.43	27.46	66.56	56.24	75.43	345.94	2*
31.00	94.43	27.46	66.56	56.24	75.43	345.94	2*
32.00	94.43	27.46	66.56	56.24	75.43	345.94	2*
33.00	94.43	27.46	66.56	56.24	75.43	345.94	2*
34.00	94.43	27.46	66.56	56.24	75.43	345.94	2*
35.00	94.43	27.46	66.56	56.24	75.43	345.94	2*
36.00	94.43	27.46	66.56	56.24	75.43	345.94	2*
37.00	94.43	27.46	66.56	56.24	75.43	345.94	2*
38.00	94.43	27.46	66.56	56.24	75.43	345.94	2*
39.00	94.43	27.46	66.56	56.24	75.43	345.94	2*
40.00	94.43	27.46	66.56	56.24	75.43	345.94	2*
41.00	94.43	27.46	66.56	56.24	75.43	345.94	2*
42.00	94.43	27.46	66.56	56.24	75.43	345.94	2*
43.00	94.43	27.46	66.56	56.24	75.43	345.94	2*
44.00	94.43	27.46	66.56	56.24	75.43	345.94	2*
45.00	94.43	27.46	66.56	56.24	75.43	345.94	2*

EUS SIMULATION PROGRAM					DATE 29 MAR 1977	PAGE	0016
46.00	247.14	23.00	224.14	482.45	933.80	4642.35	1.
47.00	247.14	23.00	224.14	482.45	933.80	4642.35	1.
48.00	247.14	23.00	224.14	482.45	933.80	4642.35	1.
49.00	247.14	23.00	224.14	482.45	933.80	4642.35	1.
50.00	247.14	23.00	224.14	482.45	933.80	4642.35	1.
51.00	247.14	23.00	224.14	482.45	933.80	4642.35	1.
52.00	247.14	23.00	224.14	482.45	933.80	4642.35	1.
53.00	247.14	23.00	224.14	482.45	933.80	4642.35	1.
54.00	247.14	23.00	224.14	482.45	933.80	4642.35	1.
55.00	247.14	23.00	224.14	482.45	933.80	4642.35	1.
56.00	247.14	23.00	224.14	482.45	933.80	4642.35	1.
57.00	247.14	23.00	224.14	482.45	933.80	4642.35	1.
58.00	247.14	23.00	224.14	482.45	933.80	4642.35	1.
59.00	247.14	23.00	224.14	482.45	933.80	4642.35	1.
60.00	247.14	23.00	224.14	482.45	933.80	4642.35	1.
61.00	247.14	23.00	224.14	482.45	933.80	4642.35	1.
62.00	247.14	23.00	224.14	482.45	933.80	4642.35	1.
63.00	247.14	23.00	224.14	482.45	933.80	4642.35	1.
64.00	247.14	23.00	224.14	482.45	933.80	4642.35	1.
65.00	247.14	23.00	224.14	482.45	933.80	4642.35	1.
66.00	247.14	23.00	224.14	482.45	933.80	4642.35	1.
67.00	247.14	23.00	224.14	482.45	933.80	4642.35	1.
68.00	247.14	23.00	224.14	482.45	933.80	4642.35	1.
69.00	247.14	23.00	224.14	482.45	933.80	4642.35	1.
70.00	247.14	23.00	224.14	482.45	933.80	4642.35	1.
71.00	247.14	23.00	224.14	482.45	933.80	4642.35	1.
72.00	247.14	23.00	224.14	482.45	933.80	4642.35	1.
73.00	247.14	23.00	224.14	482.45	933.80	4642.35	1.
74.00	247.14	23.00	224.14	482.45	933.80	4642.35	1.
75.00	247.14	23.00	224.14	482.45	933.80	4642.35	1.
76.00	247.14	23.00	224.14	482.45	933.80	4642.35	1.
77.00	247.14	23.00	224.14	482.45	933.80	4642.35	1.
78.00	247.14	23.00	224.14	482.45	933.80	4642.35	1.
79.00	247.14	23.00	224.14	482.45	933.80	4642.35	1.
80.00	247.14	23.00	224.14	482.45	933.80	4642.35	1.
81.00	247.14	23.00	224.14	482.45	933.80	4642.35	1.
82.00	247.14	23.00	224.14	482.45	933.80	4642.35	1.
83.00	247.14	23.00	224.14	482.45	933.80	4642.35	1.
84.00	247.14	23.00	224.14	482.45	933.80	4642.35	1.
85.00	247.14	23.00	224.14	482.45	933.80	4642.35	1.
86.00	247.14	23.00	224.14	482.45	933.80	4642.35	1.
87.00	247.14	23.00	224.14	482.45	933.80	4642.35	1.
88.00	247.14	23.00	224.14	482.45	933.80	4642.35	1.
89.00	247.14	23.00	224.14	482.45	933.80	4642.35	1.
90.00	247.14	23.00	224.14	482.45	933.80	4642.35	1.
91.00	247.14	23.00	224.14	482.45	933.80	4642.35	1.
92.00	247.14	23.00	224.14	482.45	933.80	4642.35	1.
93.00	247.14	23.00	224.14	482.45	933.80	4642.35	1.
94.00	247.14	23.00	224.14	482.45	933.80	4642.35	1.
95.00	247.14	23.00	224.14	482.45	933.80	4642.35	1.
96.00	247.14	23.00	224.14	482.45	933.80	4642.35	1.
97.00	247.14	23.00	224.14	482.45	933.80	4642.35	1.
98.00	247.14	23.00	224.14	482.45	933.80	4642.35	1.
99.00	247.14	23.00	224.14	482.45	933.80	4642.35	1.

TIME	ENGINE		TRANSMISSION		REAR AXLE	GEAR	
	INSTANT. ENGINE HP	ACC. HP LOSS	DYNAMIC FLYWHEEL HP	DYNAMIC CONVERTER OUTPUT HP	DYNAMIC DRIVE- SHAFT HP		DYNAMIC REAR AXLE OUTPUT HP
1+00	57.26	4.51	65.75	20.51	19.16	18.15	1*
2+00	59.48	4.99	65.49	38.23	36.20	34.68	1*
3+00	55.44	5.55	60.92	59.81	56.88	54.23	1*
4+00	107.47	6.68	103.26	77.52	74.14	71.17	1*
5+00	127.24	7.67	123.66	99.25	95.39	88.95	1*
6+00	154.55	9.21	146.17	114.42	110.17	106.42	1*
7+00	184.32	10.37	173.79	134.41	128.86	124.76	2*
8+00	223.22	10.86	195.45	150.34	145.15	141.07	2*
9+00	286.40	11.74	213.21	160.40	156.25	152.54	2*
10+00	354.40	12.70	34.68	27.26	26.40	25.44	2*
11+00	23.21	6.73	16.45	13.22	13.27	12.54	2*
12+00	23.12	6.73	16.36	13.74	13.16	12.47	2*
13+00	23.11	6.73	16.40	13.77	13.19	12.50	2*
14+00	23.13	6.73	16.40	13.77	13.19	12.50	2*
15+00	23.11	6.73	16.40	13.77	13.19	12.50	2*
16+00	23.12	6.73	16.40	13.77	13.19	12.50	2*
17+00	23.13	6.73	16.40	13.77	13.19	12.50	2*
18+00	23.13	6.73	16.40	13.77	13.19	12.50	2*
19+00	23.13	6.73	16.40	13.77	13.19	12.50	2*
20+00	23.13	6.73	16.40	13.77	13.19	12.50	2*
21+00	23.12	6.73	16.40	13.77	13.19	12.50	2*
22+00	23.13	6.73	16.40	13.77	13.19	12.50	2*
23+00	23.11	6.73	16.40	13.77	13.19	12.50	2*
24+00	23.13	6.73	16.40	13.77	13.19	12.50	2*
25+00	23.13	6.73	16.40	13.77	13.19	12.50	2*
26+00	-18.38	6.71	-25.72	-21.61	-20.84	-19.95	2*
27+00	-45.75	5.71	-13.33	-10.92	-10.44	-9.86	2*
28+00	22.45	4.84	16.25	13.65	13.63	12.95	2*
29+00	31.32	4.57	25.29	24.65	24.62	23.82	2*
30+00	24.49	3.20	35.21	29.41	29.41	28.59	2*
31+00	35.73	3.19	28.54	25.95	23.14	22.44	1*
32+00	39.16	3.34	35.10	29.49	28.49	27.44	1*
33+00	40.60	2.77	27.65	31.07	29.52	26.48	1*
34+00	36.29	3.72	32.55	22.32	21.38	20.31	1*
35+00	37.32	3.61	34.21	15.27	14.48	13.91	1*
36+00	37.00	3.53	34.45	1.14	1.06	1.03	1*
37+00	37.57	3.53	34.39	.00	.00	.00	1*
38+00	37.92	3.49	34.00	.00	.00	.00	1*
39+00	37.92	3.53	34.39	.00	.00	.00	1*
40+00	37.92	3.53	34.39	.00	.00	.00	1*
41+00	37.92	3.53	34.39	.00	.00	.00	1*

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46+00	37+92	3+53	34+39	+00	+00	+00	1*		
47+00	37+92	3+53	34+39	+00	+00	+00	1*		
48+00	37+92	3+53	34+39	+00	+00	+00	1*		
49+00	37+92	3+53	34+39	+00	+00	+00	1*		
50+00	37+92	3+53	34+39	+00	+00	+00	1*		
51+00	37+92	3+53	34+39	+00	+00	+00	1*		
52+00	37+92	3+53	34+39	+00	+00	+00	1*		
53+00	37+92	3+53	34+39	+00	+00	+00	1*		
54+00	37+92	3+53	34+45	+00	+00	+00	1*		
55+00	54+15	4+27	51+05	13+53	17+42	16+66	1*		
56+00	70+94	5+11	69+74	39+93	37+75	35+68	1*		
57+00	87+94	5+43	85+24	55+83	55+55	53+53	1*		
58+00	107+63	6+70	103+37	77+93	74+51	71+47	1*		
59+00	129+21	7+67	123+47	96+11	92+27	88+85	1*		
60+00	154+56	9+21	146+22	114+46	110+20	106+45	1*		
61+00	182+34	10+00	173+76	130+40	126+23	122+75	2*		
62+00	203+80	10+56	193+45	150+14	145+15	141+07	2*		
63+00	226+50	11+88	213+21	165+40	160+25	156+54	2*		
64+00	254+40	12+70	244+08	187+26	182+40	178+44	2*		
65+00	283+03	13+78	274+45	209+22	204+24	200+54	2*		
66+00	308+13	14+73	299+26	230+74	225+16	221+47	2*		
67+00	334+13	15+73	324+40	251+77	246+19	242+00	2*		
68+00	358+13	16+73	348+40	272+77	267+19	263+00	2*		
69+00	383+13	17+73	373+40	293+77	288+19	284+00	2*		
70+00	408+13	18+73	398+40	314+77	309+19	305+00	2*		
71+00	433+13	19+73	423+40	335+77	330+19	326+00	2*		
72+00	458+13	20+73	448+40	356+77	351+19	347+00	2*		
73+00	483+13	21+73	473+40	377+77	372+19	368+00	2*		
74+00	508+13	22+73	498+40	398+77	393+19	389+00	2*		
75+00	533+13	23+73	523+40	419+77	414+19	410+00	2*		
76+00	558+13	24+73	548+40	440+77	435+19	431+00	2*		
77+00	583+13	25+73	573+40	461+77	456+19	452+00	2*		
78+00	608+13	26+73	598+40	482+77	477+19	473+00	2*		
79+00	633+13	27+73	623+40	503+77	498+19	494+00	2*		
80+00	658+13	28+73	648+40	524+77	519+19	515+00	2*		
81+00	683+13	29+73	673+40	545+77	540+19	536+00	2*		
82+00	708+13	30+73	698+40	566+77	561+19	557+00	2*		
83+00	733+13	31+73	723+40	587+77	582+19	578+00	2*		
84+00	758+13	32+73	748+40	608+77	603+19	604+00	2*		
85+00	783+13	33+73	773+40	629+77	624+19	620+00	2*		
86+00	808+13	34+73	798+40	650+77	645+19	641+00	2*		
87+00	833+13	35+73	823+40	671+77	666+19	662+00	2*		
88+00	858+13	36+73	848+40	692+77	687+19	683+00	2*		
89+00	883+13	37+73	873+40	713+77	708+19	704+00	2*		
90+00	908+13	38+73	898+40	734+77	729+19	725+00	2*		
91+00	933+13	39+73	923+40	755+77	750+19	746+00	2*		
92+00	958+13	40+73	948+40	776+77	771+19	767+00	2*		
93+00	983+13	41+73	973+40	797+77	792+19	788+00	2*		
94+00	1008+13	42+73	998+40	818+77	813+19	809+00	2*		
95+00	1033+13	43+73	1023+40	839+77	834+19	830+00	2*		
96+00	1058+13	44+73	1048+40	860+77	855+19	851+00	2*		
97+00	1083+13	45+73	1073+40	881+77	876+19	872+00	2*		
98+00	1108+13	46+73	1098+40	902+77	897+19	893+00	2*		
99+00	1133+13	47+73	1123+40	923+77	918+19	914+00	2*		
100+00	1158+13	48+73	1148+40	944+77	939+19	935+00	2*		
101+00	1183+13	49+73	1173+40	965+77	960+19	956+00	2*		
102+00	1208+13	50+73	1198+40	986+77	981+19	977+00	2*		
103+00	1233+13	51+73	1223+40	1007+77	1002+19	998+00	2*		
104+00	1258+13	52+73	1248+40	1028+77	1023+19	1019+00	2*		
105+00	1283+13	53+73	1273+40	1049+77	1044+19	1040+00	2*		
106+00	1308+13	54+73	1298+40	1070+77	1065+19	1061+00	2*		
107+00	1333+13	55+73	1323+40	1091+77	1086+19	1082+00	2*		
108+00	1358+13	56+73	1348+40	1112+77	1107+19	1103+00	2*		
109+00	1383+13	57+73	1373+40	1133+77	1128+19	1124+00	2*		
110+00	1408+13	58+73	1398+40	1154+77	1149+19	1145+00	2*		
111+00	1433+13	59+73	1423+40	1175+77	1170+19	1166+00	2*		
112+00	1458+13	60+73	1448+40	1196+77	1191+19	1187+00	2*		
113+00	1483+13	61+73	1473+40	1217+77	1212+19	1208+00	2*		
114+00	1508+13	62+73	1498+40	1238+77	1233+19	1229+00	2*		
115+00	1533+13	63+73	1523+40	1259+77	1254+19	1250+00	2*		
116+00	1558+13	64+73	1548+40	1280+77	1275+19	1271+00	2*		
117+00	1583+13	65+73	1573+40	1301+77	1296+19	1292+00	2*		
118+00	1608+13	66+73	1598+40	1322+77	1317+19	1313+00	2*		
119+00	1633+13	67+73	1623+40	1343+77	1338+19	1334+00	2*		
120+00	1658+13	68+73	1648+40	1364+77	1359+19	1355+00	2*		
121+00	1683+13	69+73	1673+40	1385+77	1380+19	1376+00	2*		
122+00	1708+13	70+73	1698+40	1406+77	1401+19	1397+00	2*		
123+00	1733+13	71+73	1723+40	1427+77	1422+19	1418+00	2*		
124+00	1758+13	72+73	1748+40	1448+77	1443+19	1439+00	2*		
125+00	1783+13	73+73	1773+40	1469+77	1464+19	1460+00	2*		
126+00	1808+13	74+73	1798+40	1490+77	1485+19	1481+00	2*		
127+00	1833+13	75+73	1823+40	1511+77	1506+19	1502+00	2*		
128+00	1858+13	76+73	1848+40	1532+77	1527+19	1523+00	2*		
129+00	1883+13	77+73	1873+40	1553+77	1548+19	1544+00	2*		
130+00	1908+13	78+73	1898+40	1574+77	1569+19	1565+00	2*		
131+00	1933+13	79+73	1923+40	1595+77	1590+19	1586+00	2*		
132+00	1958+13	80+73	1948+40	1616+77	1611+19	1607+00	2*		
133+00	1983+13	81+73	1973+40	1637+77	1632+19	1628+00	2*		
134+00	2008+13	82+73	1998+40	1658+77	1653+19	1649+00	2*		
135+00	2033+13	83+73	2023+40	1679+77	1674+19	1670+00	2*		
136+00	2058+13	84+73	2048+40	1700+77	1695+19	1691+00	2*		
137+00	2083+13	85+73	2073+40	1721+77	1716+19	1712+00	2*		
138+00	2108+13	86+73	2098+40	1742+77	1737+19	1733+00	2*		
139+00	2133+13	87+73	2123+40	1763+77	1758+19	1754+00	2*		
140+00	2158+13	88+73	2148+40	1784+77	1779+19	1775+00	2*		
141+00	2183+13	89+73	2173+40	1805+77	1800+19	1796+00	2*		
142+00	2208+13	90+73	2198+40	1826+77	1821+19	1817+00	2*		
143+00	2233+13	91+73	2223+40	1847+77	1842+19	1838+00	2*		
144+00	2258+13	92+73	2248+40	1868+77	1863+19	1859+00	2*		
145+00	2283+13	93+73	2273+40	1889+77	1884+19	1880+00	2*		
146+00	2308+13	94+73	2298+40	1910+77	1905+19	1901+00	2*		
147+00	2333+13	95+73	2323+40	1931+77	1926+19	1922+00	2*		
148+00	2358+13	96+73	2348+40	1952+77	1947+19	1943+00	2*		
149+00	2383+13	97+73	2373+40	1973+77	1968+19	1964+00	2*		
150+00	2408+13	98+73	2398+40	1994+77	1989+19	1985+00	2*		
151+00	2433+13	99+73	2423+40	2015+77	2010+19	2006+00	2*		
152+00	2458+13	00+73	2448+40	2036+77	2031+19	2027+00	2*		
153+00	2483+13	01+73	2473+40	2057+77	2052+19	2048+00	2*		
154+00	2508+13	02+73	2498+40	2078+77	2073+19	2069+00	2*		
155+00	2533+13	03+73	2523+40	2099+77	2094+19	2090+00	2*		
156+00	2558+13	04+73	2548+40	2120+77	2115+19	2111+00	2*		
157+00	2583+13	05+73	2573+40	2141+77	2136+19	2132+00	2*		
158+00	2608+13	06+73	2598+40	2162+77	2157+19	2153+00	2*		
159+00	2633+13	07+73	2623+40	2183+77	2178+19	2174+00	2*		
160+00	2658+13	08+73	2648+40	2204+77	2199+19	2195+00	2*		
161+00	2683+13	09+73	2673+40	2225+77	2220+19	2216+00	2*		
162+00	2708+13	10+73	2698+40	2246+77	2241+19	2237+00	2*		
163+00	2733+13	11+73	2723+40	2267+77	2262+19	2258+00	2*		
164+00	2758+13	12+73	2748+40	2288+77	2283+19	2279+00	2*		
165+00	2783+13	13+73	2773+40	2309+77	2304+19	2300+00	2*		
166+00	2808+13	14+73	2798+40	2330+77	2325+19	2321+00	2*		
167+00	2833+13	15+73	2823+40	2351+77	2346+19	2342+00	2*		
168+00	2858+13	16+73	2848+40	2372+77	2367+19	2363+00	2*		
169+00	2883+13	17+73	2873+40	2393+77	2388+19	2384+00	2*		
170+00	2908+13	18+73	2898+40	2414+77	2409+19	2405+00	2*		
171+00	2933+13	19+73	2923+40	2435+77	2430+19	2426+00	2*		
172+00	2958+13	20+73	2948+40	2456+77	2451+19	2447+00	2*		
173+00	2983+13	21+73							

BUS SIMULATION PROGRAM							DATE 29 MAR 1977	PAGE	0020
09.00	37.02	3.53	34.39	.00	.20	.00	1.		
100.00	37.02	3.53	34.39	.00	.20	.00	1.		
101.00	37.02	3.53	34.39	.00	.20	.00	1.		
102.00	37.02	3.53	34.39	.00	.20	.00	1.		
103.00	37.02	3.53	34.39	.00	.20	.00	1.		
104.00	37.02	3.53	34.39	.00	.20	.00	1.		
105.00	37.02	3.53	34.39	.00	.20	.00	1.		
106.00	37.02	3.53	34.39	.00	.20	.00	1.		
107.00	37.02	3.53	34.39	.00	.20	.00	1.		
108.00	37.02	3.53	34.39	.00	.20	.00	1.		
109.00	39.64	3.53	34.45	.00	.20	.00	1.		
110.00	50.15	4.27	51.25	13.53	17.42	16.05	1.		
111.00	70.34	5.11	69.76	33.92	37.75	35.88	1.		
112.00	87.84	5.83	85.64	58.15	55.68	53.53	1.		
113.00	107.12	6.70	103.67	77.53	74.51	71.47	1.		
114.00	128.11	7.67	123.77	97.11	92.27	88.35	1.		
115.00	150.61	9.21	146.22	114.46	108.20	103.43	1.		
116.00	174.74	10.30	163.78	130.40	123.35	117.75	2.		
117.00	200.40	10.56	195.45	150.34	145.15	141.07	2.		
118.00	227.40	11.54	213.71	164.43	160.25	156.54	2.		
119.00	255.40	12.77	244.68	177.26	174.40	170.44	2.		
120.00	284.00	6.73	284.43	177.22	177.24	173.54	2.		
121.00	284.13	6.73	284.36	177.24	177.15	173.47	2.		
122.00	284.13	6.73	284.40	177.22	177.15	173.50	2.		
123.00	284.13	6.73	284.40	177.22	177.19	173.50	2.		
124.00	284.13	6.73	284.40	177.22	177.19	173.50	2.		
125.00	284.13	6.73	284.40	177.22	177.19	173.50	2.		
126.00	284.13	6.73	284.40	177.22	177.19	173.50	2.		
127.00	284.13	6.73	284.40	177.22	177.19	173.50	2.		
128.00	284.13	6.73	284.40	177.22	177.19	173.50	2.		
129.00	284.13	6.73	284.40	177.22	177.19	173.50	2.		
130.00	284.13	6.73	284.40	177.22	177.19	173.50	2.		
131.00	284.13	6.73	284.40	177.22	177.19	173.50	2.		
132.00	284.13	6.73	284.40	177.22	177.19	173.50	2.		
133.00	284.13	6.73	284.40	177.22	177.19	173.50	2.		
134.00	284.13	6.73	284.40	177.22	177.19	173.50	2.		
135.00	284.13	6.73	284.40	177.22	177.19	173.50	2.		
136.00	284.13	6.73	284.40	177.22	177.19	173.50	2.		
137.00	284.13	6.73	284.40	177.22	177.19	173.50	2.		
138.00	284.13	6.73	284.40	177.22	177.19	173.50	2.		
139.00	284.13	6.73	284.40	177.22	177.19	173.50	2.		
140.00	284.13	6.73	284.40	177.22	177.19	173.50	2.		
141.00	284.13	6.73	284.40	177.22	177.19	173.50	2.		
142.00	284.13	6.73	284.40	177.22	177.19	173.50	2.		
143.00	284.13	6.73	284.40	177.22	177.19	173.50	2.		
144.00	284.13	6.73	284.40	177.22	177.19	173.50	2.		
145.00	284.13	6.73	284.40	177.22	177.19	173.50	2.		
146.00	284.13	6.73	284.40	177.22	177.19	173.50	2.		
147.00	284.13	6.73	284.40	177.22	177.19	173.50	2.		
148.00	284.13	6.73	284.40	177.22	177.19	173.50	2.		
149.00	284.13	6.73	284.40	177.22	177.19	173.50	2.		
150.00	284.13	6.73	284.40	177.22	177.19	173.50	2.		
151.00	284.13	6.73	284.40	177.22	177.19	173.50	2.		
152.00	284.13	6.73	284.40	177.22	177.19	173.50	2.		
153.00	284.13	6.73	284.40	177.22	177.19	173.50	2.		
154.00	284.13	6.73	284.40	177.22	177.19	173.50	2.		
155.00	284.13	6.73	284.40	177.22	177.19	173.50	2.		
156.00	284.13	6.73	284.40	177.22	177.19	173.50	2.		
157.00	284.13	6.73	284.40	177.22	177.19	173.50	2.		
158.00	284.13	6.73	284.40	177.22	177.19	173.50	2.		
159.00	284.13	6.73	284.40	177.22	177.19	173.50	2.		
160.00	284.13	6.73	284.40	177.22	177.19	173.50	2.		
161.00	284.13	6.73	284.40	177.22	177.19	173.50	2.		
162.00	284.13	6.73	284.40	177.22	177.19	173.50	2.		
163.00	284.13	6.73	284.40	177.22	177.19	173.50	2.		
164.00	284.13	6.73	284.40	177.22	177.19	173.50	2.		
165.00	284.13	6.73	284.40	177.22	177.19	173.50	2.		
166.00	284.13	6.73	284.40	177.22	177.19	173.50	2.		
167.00	284.13	6.73	284.40	177.22	177.19	173.50	2.		
168.00	284.13	6.73	284.40	177.22	177.19	173.50	2.		
169.00	284.13	6.73	284.40	177.22	177.19	173.50	2.		
170.00	284.13	6.73	284.40	177.22	177.19	173.50	2.		
171.00	284.13	6.73	284.40	177.22	177.19	173.50	2.		
172.00	284.13	6.73	284.40	177.22	177.19	173.50	2.		
173.00	284.13	6.73	284.40	177.22	177.19	173.50	2.		
174.00	284.13	6.73	284.40	177.22	177.19	173.50	2.		
175.00	284.13	6.73	284.40	177.22	177.19	173.50	2.		
176.00	284.13	6.73	284.40	177.22	177.19	173.50	2.		
177.00	284.13	6.73	284.40	177.22	177.19	173.50	2.		
178.00	284.13	6.73	284.40	177.22	177.19	173.50	2.		
179.00	284.13	6.73	284.40	177.22	177.19	173.50	2.		
180.00	284.13	6.73	284.40	177.22	177.19	173.50	2.		
181.00	284.13	6.73	284.40	177.22	177.19	173.50	2.		
182.00	284.13	6.73	284.40	177.22	177.19	173.50	2.		
183.00	284.13	6.73	284.40	177.22	177.19	173.50	2.		
184.00	284.13	6.73	284.40	177.22	177.19	173.50	2.		
185.00	284.13	6.73	284.40	177.22	177.19	173.50	2.		
186.00	284.13	6.73	284.40	177.22	177.19	173.50	2.		
187.00	284.13	6.73	284.40	177.22	177.19	173.50	2.		
188.00	284.13	6.73	284.40	177.22	177.19	173.50	2.		
189.00	284.13	6.73	284.40	177.22	177.19	173.50	2.		
190.00	284.13	6.73	284.40	177.22	177.19	173.50	2.		
191.00	284.13	6.73	284.40	177.22	177.19	173.50	2.		
192.00	284.13	6.73	284.40	177.22	177.19	173.50	2.		
193.00	284.13	6.73	284.40	177.22	177.19	173.50	2.		
194.00	284.13	6.73	284.40	177.22	177.19	173.50	2.		
195.00	284.13	6.73	284.40	177.22	177.19	173.50	2.		
196.00	284.13	6.73	284.40	177.22	177.19	173.50	2.		
197.00	284.13	6.73	284.40	177.22	177.19	173.50	2.		
198.00	284.13	6.73	284.40	177.22	177.19	173.50	2.		
199.00	284.13	6.73	284.40	177.22	177.19	173.50	2.		
200.00	284.13	6.73	284.40	177.22	177.19	173.50	2.		

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